KWAZULU-NATAL PROVINCE

EDUCATION
REPUBLIC OF SOUTH AFRICA

CURRICULUM GRADE 10 -12 DIRECTORATE

# NCS (CAPS)

# LEARNER SUPPORT DOCUMENT

# GRADE 10

# PHYSICAL SCIENCES REVISION DOCUMENT

2024

# PREFACE

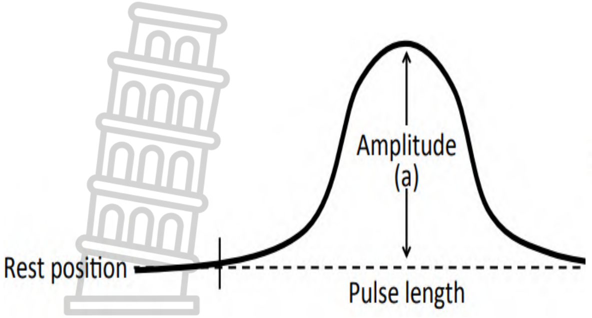
This support document serves to assist Physical Sciences learners on how to deal with curriculum gaps and learning losses. It addresses all the topics in the Grade 10 curriculum.

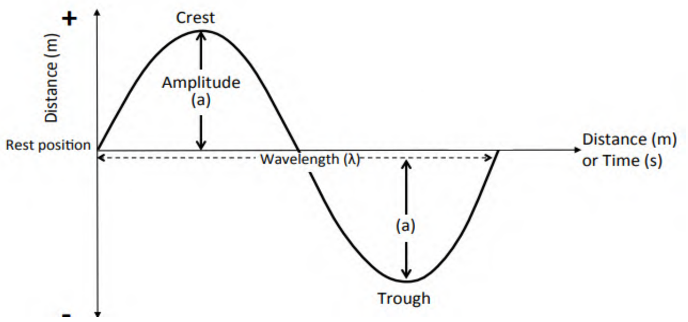
Activities serve as a guide on how various topics are assessed at different cognitive levels and to prepare learners for informal and formal tasks in Physical Sciences. It covers the following topics:

| **TERM 1 TOPICS** |
|---|
| WAVES, SOUND AND LIGHT<br>• ELECTROMAGNETIC RADIATION |
| ELECTRICITY AND MAGNETISM<br>• ELECTROSTATICS AND ELECTRIC CIRCUITS |
| **TERM 2 TOPICS** |
| ELECTRICITY AND MAGNETISM<br>• ELECTRIC CIRCUITS |
| MATTER AND MATERIALS<br>• STATES OF MATTER & KMT<br>• THE ATOM<br>• THE PERIODIC TABLE<br>• CHEMICAL BONDING |
| CHEMICAL CHANGE<br>• PHYSICAL CHANGE AND CHEMICAL CHANGE<br>• REPRESENTING CHEMICAL CHANGE<br>• QUANTITATIVE ASPECTS OF CHEMICAL CHANGE |
| **TERM 3 TOPICS** |
| CHEMICAL CHANGE<br>• QUANTITATIVE ASPECTS OF CHEMICAL CHANGE<br>MECHANICS<br>• VECTORS & SCALARS<br>• MOTION IN ONE DIMENSION<br>• INSTANTANEOUS SPEED AND VELOCITY & EQUATIONS OF MOTION |
| **TERM 4 TOPICS** |
| **MECHANICS**<br>• ENERGY |

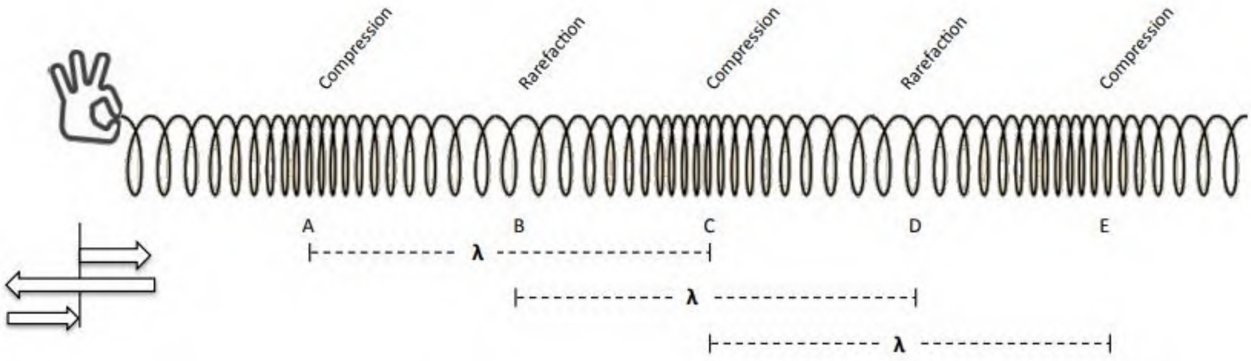
**WAVES, SOUND AND LIGHT**
**SUMMARY**

TRANSVERSE WAVE



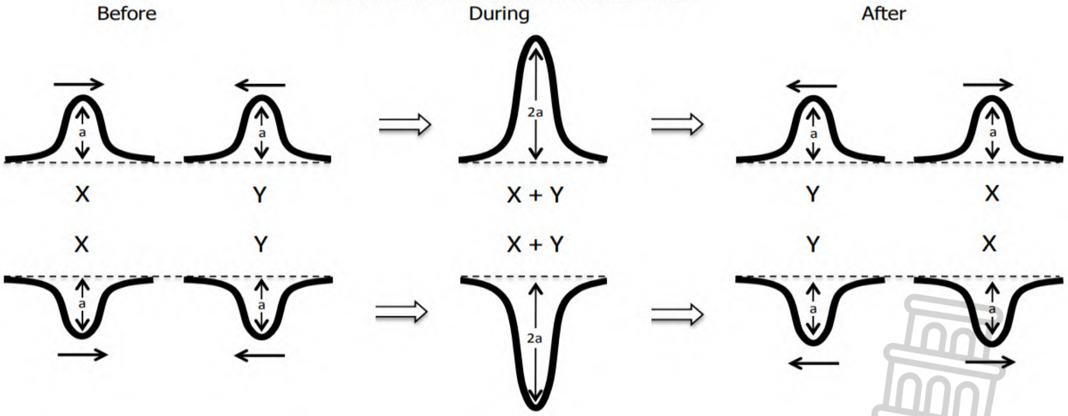

**LONGITUDINAL WAVE**



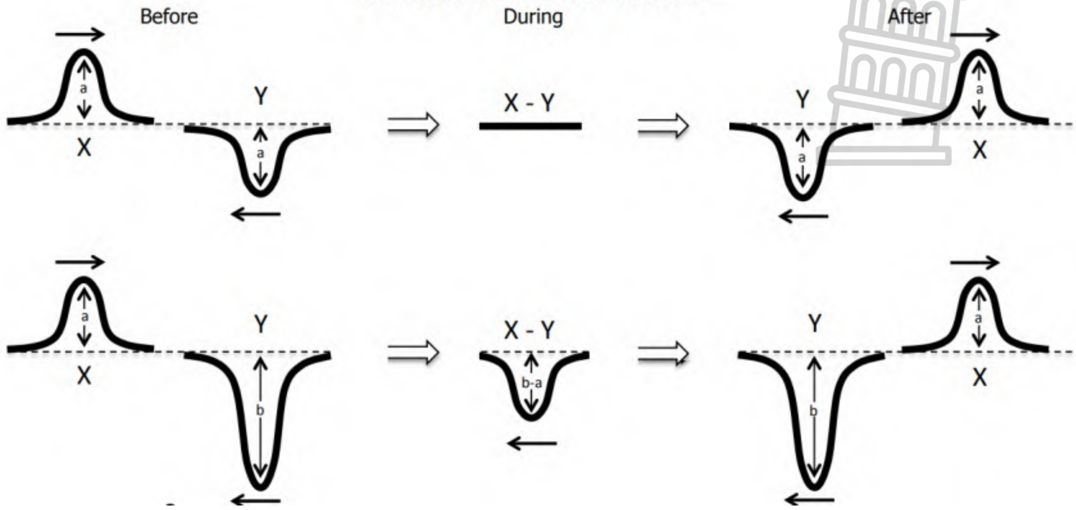

**WHAT HAPPENS WHEN TWO WAVES MEET?**

**When two pulses meet:**

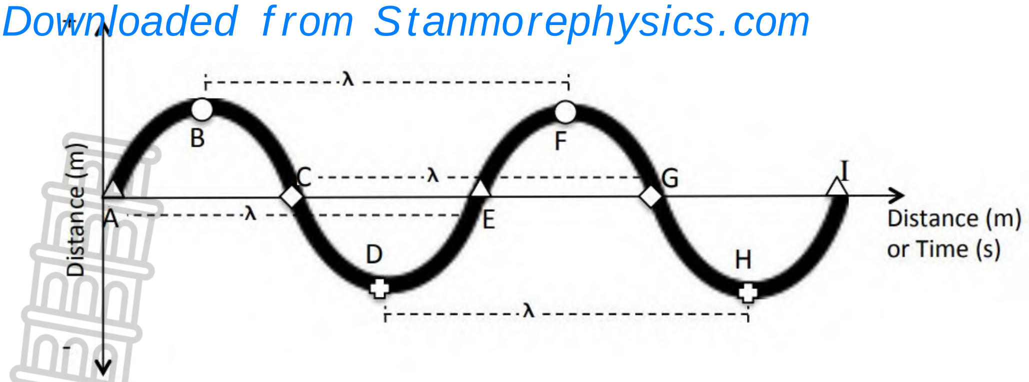
**CONSTRUCTIVE INTERFERENCE**




**DESTRUCTIVE INTERFERENCE**




**MULTIPLE TRANSVERSE WAVES**




**IN phase:**
A – E
B – F
A – I
D – H

**TOTALLY OUT of phase:**
A – C
B – D
A - G
D – F

**PARTIALY OUT of phase:**
A – B
B – E
A - F
D – E

**USEFUL FORMULAE**

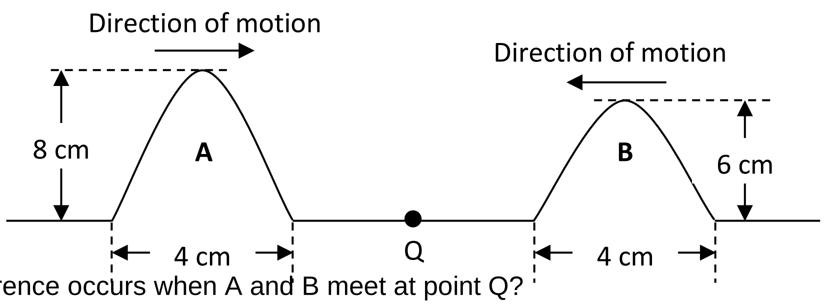
$v = f\lambda$

$T = \frac{1}{f}$

$E = hf$ or $E = h\frac{c}{\lambda}$

EXAMPLE 1

The two pulses, **A** and **B**, in a string are approaching each other, as shown in the diagram below. The amplitudes of pulses **A** and **B** are 8 cm and 6 cm respectively and they meet at point **Q**. Assume that no energy is lost.




1.1 What type of interference occurs when A and B meet at point Q? (1)

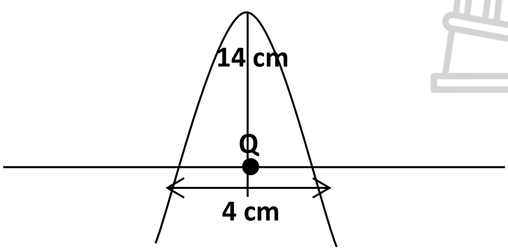
1.2 Use the graph paper provided to draw a sketch that shows the resulting pulse when A and B meet at point Q. Show all relevant measurements (3)

1.3 Write down the magnitude and direction of the amplitude of pulse B after A and B have met at point Q. (1)

SOLUTIONS

1.1 Constructive interference (1)

1.2 (3)

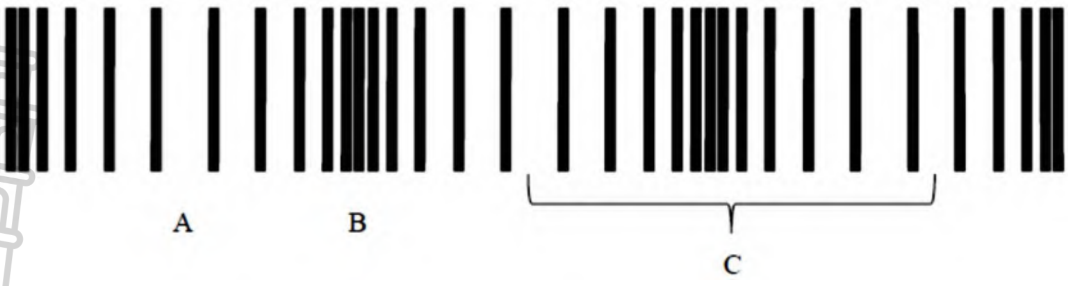



| Criterion | Mark |
|---|---|
| • Correct size of pulse width | ✓ |
| • Correct new amplitude | ✓ |
| • Correct measurements | ✓ |

1.3 8cm, to the left (or west or in the original direction.) ✓ (1)

EXAMPLE 2

The diagram below shows different points on a longitudinal wave.




2.1 Write down the labels for A, B and C (3)

2.2 Does this type of medium require a medium to propagate? (1)

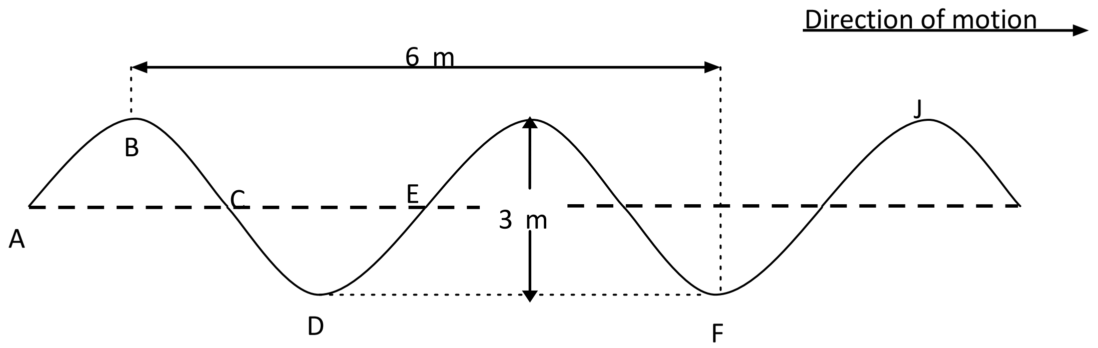
SOLUTION

2.1 A: rarefaction ✓ (3)
B: compression ✓
C: wavelength ✓

2.2 YES ✓ (1)

EXAMPLE 3

The diagram below represents a water wave moving from left to right. The time between two consecutive crests is 0,5 s.




3.1 What type of wave is a water wave? (1)

3.2 Write down the amplitude of the wave. (1)

3.3 Determine the wavelength of the wave (1)

3.4 Name two points on the wave above that are in phase (1)

3.5 Calculate the time taken for four crests to move past a certain point in the path of the wave (2)

3.6 Calculate the speed of the wave (3)

SOLUTIONS

3.1 Transverse ✓

3.2 1,5 m ✓ (1)

3.3 λ = 4 m (6 m =1,5 waves) ✓ (1)

3.4 Any one of: A and E; B and J; D and F ✓ (1)

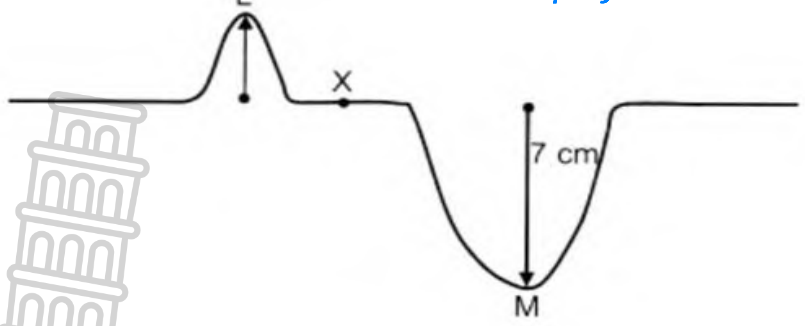
3.5 4 crests imply 3 waves ✓ (2)
3 x 0,5 = 1,5 s (3 waves x 0,5 seconds per wave) ✓

3.6 v= f λ✓ (3)
$= (1/T)\,\lambda$
$= (1/0.5)4$✓
= 8 m.s$^{-1}$✓

**ACTIVITIES**

**1.1** Define the term pulse (2)

1.2 The diagram below shows two pulses L and M, traveling in opposite directions in a rope. The amplitude of pulse L is UNKNOWN and that of pulse M is 7cm.
The two pulses meet at point X and the resulting amplitude is shown.




1.2.1 What type of interference take place at X? (1)
1.2.2 Why is it possible to apply the principle of superposition at X? (1)
1.2.3 Determine the amplitude of L (1)
1.2.4 In which direction does pulse M move AFTER the 2 pulses pass each other? Write either TO THE LEFT or TO THE RIGHT (1)

**QUESTION 2**

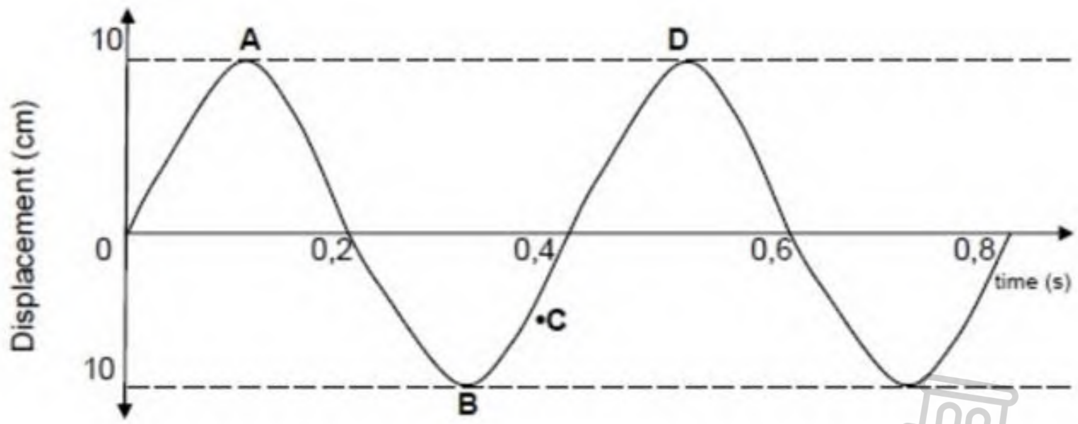
2.1 The distance between 13 consecutive crests in a ripple tank is 1.8m. The waves travel through the water at a speed of 0.225m.s$^{-1}$.

2.1.1 Define the term wavelength of a wave (2)

2.2 Calculate the….

2.2.1 Wavelength of the wave, in meters (3)
2.2.2 Frequency of the wave (3)

2.3 The graph below shows the displacement of a leaf on a dam at an interval of 0.2s after a disturbance has moved through the water at 12m.s$^{-1}$. The wave moves from left to right in the diagram.




2.3.1 At position C, is the leaf moving upwards or downwards? (1)
2.3.2 Consider the points A, B, C and D in the diagram. Identify TWO points which are in phase. (1)

2.4 Calculate ……

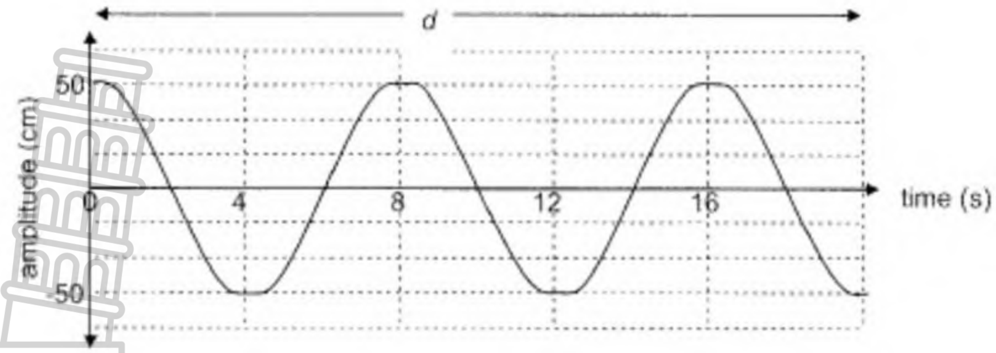
2.4.1 The frequency of the wave (2)
2.4.2 Wavelength produced (3)

2.5 What is meant by the term amplitude of a wave (2)

2.6 The amplitude of the wave is now doubled. What is the value, in metres, of the new amplitude of the wave? (2)

**QUESTION 3**

The diagram below represents a transverse wave produced by **source A**

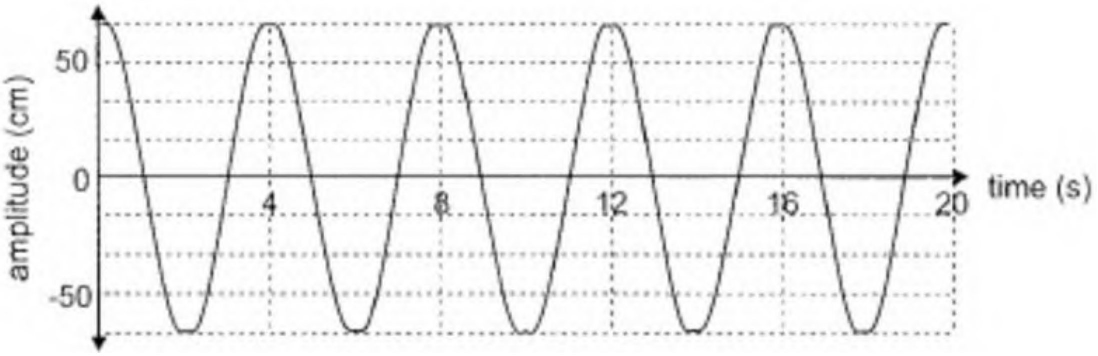



3.1 Calculate the .....

3.1.1 Speed of the wave if the wavelength is 0.8m (5)

3.1.2 Distance d on the diagram (2)

The diagram below represents the transverse wave produced by **source B**




3.2 How does each of the following properties of the wave produced by source B compared to that of the wave produced by source A? Choose from GREATER THAN, SMALLER THAN or EQUAL TO.

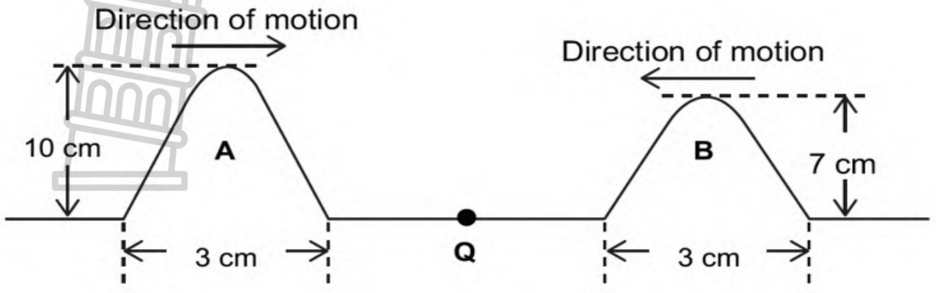
3.2.1 Amplitude (1)

3.2.2 Frequency (1)

3.3 Calculate the frequency of the wave produced by source B (3)

**QUESTION 4**

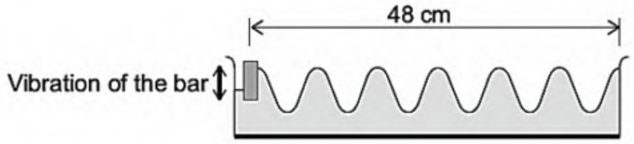
Two pulses, A and B, travelling along a string, approach each other. The amplitudes of the pulses are 10cm and 7cm respectively. They meet at point Q. Assume that no energy is lost.




4.1 Define the term *pulse.* (2)
4.2 Name the phenomenon that occurs when A and B meet at point Q. (2)
4.3 State *the principle of superposition* (2)
4.4 Draw a sketch to show the resulting pulse when A and B meet at point Q. Show all relevant measurements. (3)
4.5 What happens to pulse B AFTER pulse A and B met?
Choose your answer from ONE of the following:
A. Moves to the right (1)
B. Becomes stationary OR
C. Moves to the left
4.6 Pulse A travels 60m in 2 minutes. Calculate the speed of pulse A. (3)

**QUESTION 5**

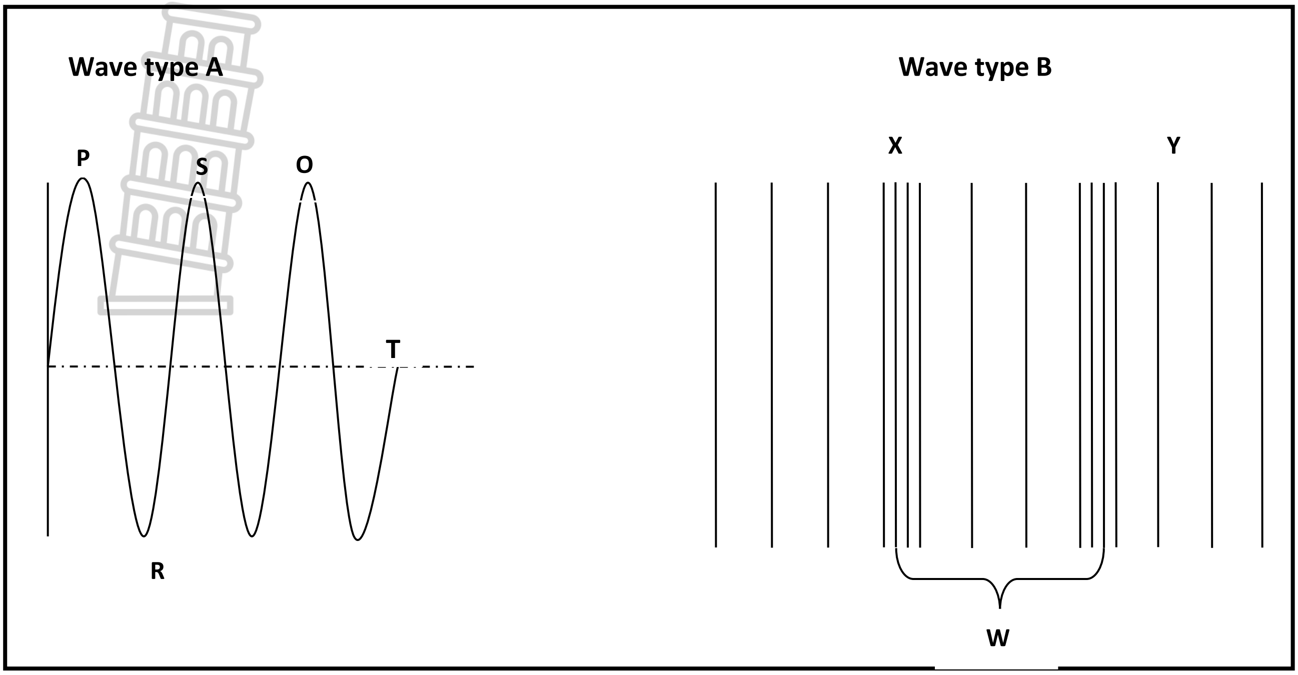
Water waves can be made by vibrating a wooden bar up and down in a tray of water. The bar moves up and down at a frequency of 5 Hz.




5.1 How many complete waves are there in 48cm? (2)
5.2 Are the water waves longitudinal or transverse? Explain briefly. (3)
5.3 Calculate the period of the waves. (3)
5.4 Calculate the speed of the water waves. (4)

**QUESTION 6**

The two diagrams below, wave type A and wave type B represent the two types of waves. Study the waves and answer the QUESTIONs that follow.




| | | |
|---|---|---|
| 6.1 | Identify **and** define wave type A. | (3) |
| 6.2 | Give one difference between wave types A and B. | (2) |
| 6.3 | Name the parts labelled R, O, W, and X. | (4) |
| 6.4 | How many complete waves cycles are in wave type A? | (1) |
| 6.5 | Calculate the frequency of the wave in type A if the time taken for the wave to reach point T in 0,3 s. | (3) |
| 6.6 | What time does it take for a wave in type A to complete one cycle? | (1) |
| 6.7 | Name the physical quantity described in 6.6. | (1) |
| 6.8 | Points O and S are in phase. | (1) |
| | 6.8.1 Explain what is meant by 'points in phase' | (1) |
| | 6.8.2 Identify any other two points that are in phase. | (1) |
| 6.9 | The amplitude in wave type A is 0; 2 m. Define the term **amplitude**. | (2) |
| 6.10 | What quantity of the sound wave is given by the amplitude? | (1) |
| 6.11 | If the distance OS is 0, 3 m, calculate the speed of this wave. | (3) |
| | | [23] |

**SOLUTIONS: WAVES**

**QUESTION 1:**

1.1 A single disturbance in a medium✓✓ (2)
1.2.1 Destructive Interference✓ (1)
1.2.2 Crest of one pulse overlaps with the trough of another✓ (1)
1.2.3 **+3cm** + (-7cm) = -4cm= 4cm (trough) ✓ (1)
1.2.4 Left✓ (1)

**QUESTION 2:**

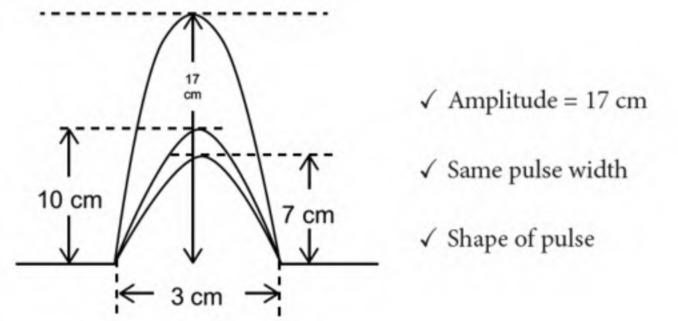
2.1.1 The distance between two consecutive points in phase✓✓ (2)
2.2.1 1.8 ✓/12✓ = 0,15m✓ (3)
2.2.2 $v = f\lambda$ ✓ (3)
F= 0,225/0.15✓
= 1,5Hz✓
2.3.1 Downwards✓ (1)
2.3.2 A and D✓ (1)
2.4.1 T= 1/f✓ (2)
f= 1/T
= 1/0,4
= 2,5Hz✓
2.4.2 $v = f\lambda$ (3)
Wavelength= v/f✓
= 12/2,5✓
= 4,8m✓
2.5 Maximum displacement of a particle from its equilibrium position✓✓ (2)
2.6 20cm✓✓ (2)

**QUESTION 3:**

3.1.1 $v = f\lambda$ ✓ (5)
= 0,125x 08✓
= 0.1ms$^{-1}$ ✓ T=1/f ✓
f = 1/T= 1/8 = 0,125Hz✓
3.1.2 2,5x 0,8 = 2m✓✓ (2)
3.2.1 Equal to✓ (1)
3.2.2 Increases✓ (1)
3.3 f=1/T✓= ¼ ✓= 0,25H✓z (3)

**QUESTION 4:**

4.1 A pulse is a single disturbance✓ (2)
4.2 Constructive✓ interference✓ (2)
4.3 The amplitude of the resultant pulse✓ (wave) is the algebraic sum of their individual amplitudes✓ (2)
4.4 (3)




4.5 C ( It continues moving in its original direction)√ (1)
4.6 V= distance/ time (method) ✓ (3)
= 60/2x60 ✓ (conversion of minutes to seconds, substitutions)
= 0,5ms$^{-1}$ ✓ ( accuracy, SI units)

**QUESTION 5:**

5.1 6 ✓✓ (2)

5.2 Transverse✓ The direction of disturbance is perpendicular to the direction of propagation✓✓ (3)

5.3 T= 1/f✓ (3)
= 1/5 ✓
= 0,2s ✓

5.4 V= distance/ time✓ (4)
= 0,48/ 6x0,2✓
= 0,4 $ms^{-1}$✓

**QUESTION 6**

6.1 Transverse wave ✓ : a succession of transverse pulses✓✓ (3)
OR
Wave propagated at right angles to the pulse.

6.2 (2)

| Transverse (A) | Longitudinal (B) |
|---|---|
| • Particles of the medium move perpendicular to the direction of propagation of the wave ✓ | • Particles move parallel to the direction of propagation of the wave ✓ |

6.3 R : trough✓ (4)
O : crest ✓
W : wavelength✓
X : compression ✓

6.4 3 waves ✓ (1)

6.5 (3)

$$f = \frac{\text{number of waves}}{\text{time taken}} \checkmark$$

$$= \frac{3}{0,3} \checkmark$$

$$= 10 \text{ Hz} \checkmark$$

6.6 (1)

$$T = \frac{1}{f} = \frac{1}{10} = 0,1\text{s} \checkmark$$

6.7 period ✓ (1)

6.8.1 points in phase are separated by the whole number multiple of whole wave cycles. ✓✓ (2)

6.8.2 P and O /P and S / S and O✓ (1)

6.9 Amplitude is the maximum disturbance of a particle from its rest (equilibrium) position. ✓✓ (2)

6.10 volume (loudness) ✓ (1)

6.11 c = fλ ✓ from 6,5 (3)
= 10 x 0,3 ✓
= 3 $m.s^{-1}$ ✓

**SOUND WAVES**

**SUMMARY NOTES**

- A sound wave is an example of a longitudinal wave.
- Sound waves are created by vibrations in a medium in the direction of propagation.
- Sound waves cannot be propagated in a vacuum.
- The speed of sound depends on the properties of a medium; sound waves travel faster in a medium whose particles are closely packed.
- Sound waves travel faster through liquids, like water, than through the air because water is denser than air.
- Sound waves travel faster in solids than in liquid because a solid is denser than liquid.

| Medium | Speed ($m.s^{-1}$) |
|---|---|
| Air | 340 |
| Water | 1500 |
| Steel | 5900 |

**ECHOES**

- Sound waves can be reflected by hard surfaces like walls and cliffs. The reflected sound is called an echo.

**Example**

A man stands between two tall buildings. When he claps his hands, he hears the echo from one building after two seconds and the echo from the other building after three seconds. Calculate the distance that the building are apart from each other. Take the speed of sound as 330 $m.s^{-1}$.

**<u>Solution.</u>**
<u>For building 1</u>
Distance = speed × time✓
Distance = 330 × 1✓
Distance =330 m. ✓

<u>For building 2</u>
Distance = speed × time✓
Distance = 330 × 1.5✓
Distance = 495 m.
Distance between 2 buildings = 330 + 495 = 825m. ✓

**CHARACTERISTICS OF SOUND**
**PITCH**
- The frequency of a sound wave is what your ear understands as pitch.
- The pitch represents how high or how low the note sounds.
- A higher frequency sound has a higher pitch, and a lower frequency sound has a lower pitch. (Frequency is directly proportional to pitch)

**LOUDNESS**
- The amplitude of a sound wave determines its loudness or volume. Loudness is the listener's evaluation of amplitude.
- A larger amplitude means a louder sound and a smaller amplitude means a softer sound. (Loudness is directly proportional to the amplitude)
- Loudness is measured in decibels (dB)

**TONE**
- The tone is a measure of the quality of the sound wave
- Sound produced by the drum not of quality because it has different frequencies and it lasts for a short while. (this is noise)

**PRACTICAL ACTIVITIES**
- Blow three vuvuzelas of different sizes to demonstrate the different frequencies (pitches)
- Blow one Vuvuzela firstly louder and then softer to demonstrate loudness.
- Blow a Vuvuzela and  a flute to demonstrate the different tones

**<u>EXAMPLE</u>**

Two musical notes have the same amplitude but note A has twice the frequency of note B. In which respects would:
(a) their sounds differ; and
(b) their sounds be the same?

**<u>Solution</u>**
*a)* Pitch✓
*b)* Loudness✓

**ULTRASOUND**
- Ultrasound is sound with a frequency that is **higher than 20 kHz.**
- The most common use of ultrasound is **to create images**.
- The use of ultrasound to create images is based on the **reflection and transmission** of a wave at a boundary.
- When an ultrasound wave travels inside an object that is made up of different materials, part of the wave is reflected and part of it is transmitted.
- The reflected rays are detected and used to construct an image of the object.

**USES OF ULTRASOUND**
**In medicine:**
- To visualise muscle and soft tissue, e.g., during pregnancy
- To generate local heating in biological tissue e.g., to break up kidney stones.

**In industry:**
- Ultrasonic cleaners are used to clean jewellery, lenses and other optical parts, watches, dental instruments, surgical instruments, and industrial parts.

**EXAMPLE**

The picture below is an ultrasound picture showing the baby inside the womb of a pregnant woman .


(1) What is an ultrasound?
(2) Briefly explain how an image is formed when using ultrasound.
(3) Describe any other use of ultrasound in medicine

**SOLUTIONS**

(1) Ultrasound is a sound with a frequency higher than 20 000Hz. ✓
(2) When an ultrasound wave travels inside an object that is made up of different materials, part of the wave is reflected and part of it is transmitted. The reflected rays are detected and used to construct an image of the object. ✓
(3) To visualise muscle and soft tissue, e.g., during pregnancy
To generate local heating in biological tissue e.g., to break up kidney stones. ✓

**ACTIVITIES**

**QUESTION 1**

Multiple choice questions

1 1.1 Ultrasound is a reflection of…? (2)
A: Soft tissues only
B: Hard tissue only
C: Both soft tissues and hard tissues
D: Hard muscles only.

1.2 The velocity of a sound is much higher in…? (2)
A: Liquid
B: Metal
C: Vacuum
D: both A and B

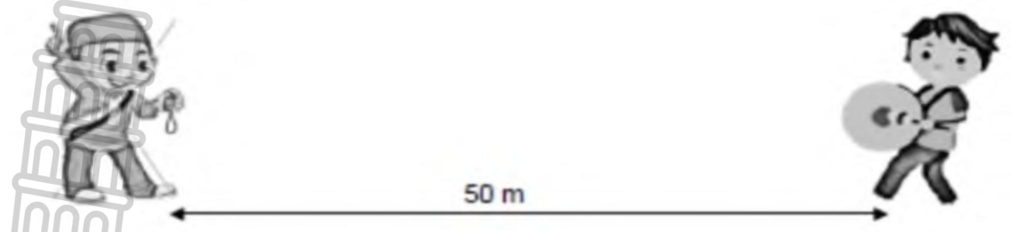
1.3 Which one of the following combinations concerning pitch and loudness is correct? (2)

| | **PITCH** | **LOUDNESS** |
|---|---|---|
| A | Frequency | Speed of vibration |
| B | Frequency | Amplitude of vibration |
| C | Amplitude of vibration | Frequency |
| D | Speed of vibration | Frequency |

1.4. What type of wave is ultrasound?
A Transverse
B Longitudinal
C Electromagnetic
D Rectangular

**QUESTION 2** 

Experiments were done to investigate the effect of temperature on the speed of sound. One person beat a drum while another person, who was standing 50m away from the sound source, recorded the time travelled by the sound.




They performed the experiment at different temperatures at different times of the day. They recorded their findings in the table below.

| TEMPERATURE ($^0$C) | TIME (s) |
|---|---|
| 0 | 0,151 |
| 5 | 0,150 |
| 10 | 0,148 |
| 15 | 0,147 |
| 20 | 0,146 |
| 25 | 0,145 |

2.1

For the investigation, write down the:

2.1.1 Investigative QUESTION (2)

2.1.2 Independent variables. (1)

2.1.3 Dependent variable (1)

2.2. Calculate the speed of sound at 20$^0$C. (3)

2.3. Write down a conclusion for the investigation. (2)

**QUESTION 3**

A longitudinal wave with a wavelength of 3cm travels through air at a speed of 330ms$^{-1}$.

3.1 Calculate the frequency of this vibration. (3)

3.2 Can a person with a normal range of hearing hear the sound of this wave? Explain briefly. (2)

**QUESTION 4**

During pregnancy, an unborn fetus is monitored using ultrasound.

4.1 Define the term "ultrasound" (2)

4.2 Briefly explain how ultrasound waves can be used to produce an image of a fetus. (2)

4.3 Give two reasons why ultrasound is used instead of X-rays when monitoring the development of the fetus. (2)

4.4 Give another non-medical use of ultrasound technology. (2)

**SOLUTIONS: SOUND**

1 1.1 C✓✓ (2)
1.2 D✓✓ (2)
1.3 B✓✓ (2)
1.4 B✓✓ (2)

2.1 2.1.1 What is the relationship between the speed of sound and the temperature? ✓✓ (2)
2.1.2 Temperature (1)
2.1.3 Speed of sound (1)

2.2 Speed = $\frac{distance}{time}$✓ (3)

Speed = $\frac{50}{0,146}$✓

Speed =342,47 m.s$^{-1}$✓

2.3 The speed of sound increases, as the temperature increases. ✓✓ (2)

3 3.1 $v = f\lambda$ ✓ (3)
330=f x 0,03✓
f= 11000 Hz✓

3.2 Yes✓. The range of human hearing is from 20Hz to 20000Hz, and this frequency fits within that range✓ (2)

4 4.1 Sound waves with frequencies higher than 20000Hz are called ultrasound✓✓ (2)

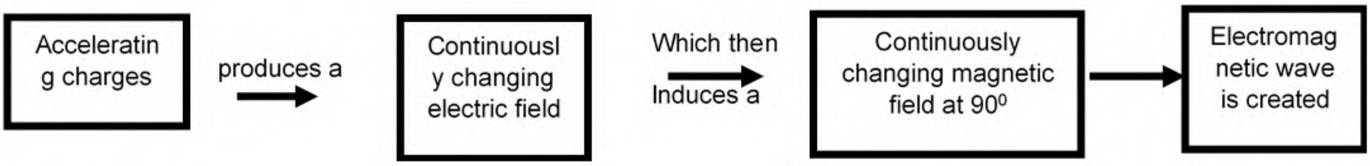
4.2 A transducer sends ultrasound waves into a woman's abdomen. These waves reflect off the tissues and are received by the transducer. A digital image of the tissues is displayed on a computer monitor. This image gives details about the unborn fetus. ✓✓ (2)

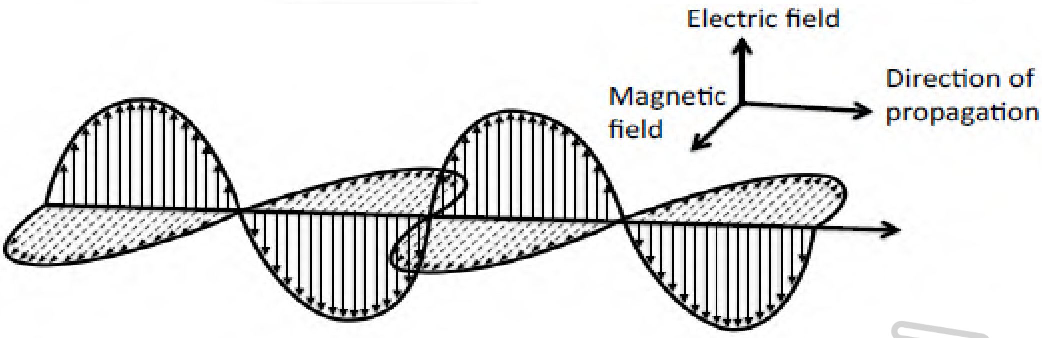
4.3 (1) Ultrasound is safe, it has no ionising radiation (which X-rays have) ✓ (2)
(2) It gives a very clear picture (image) of soft tissue which X-rays are not able to do✓

4.4 SONAR uses ultrasound for depth sounding, locating shoals of fish etc. ✓✓ (2)

**ELECTROMAGNETIC RADIATION**
**SUMMARY NOTES**
**WAVE NATURE OF ELECTROMAGNETIC RADIATION**

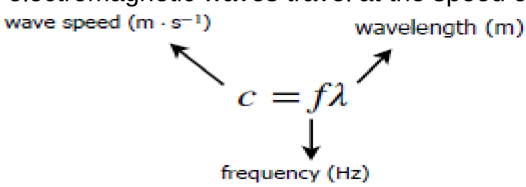
- It is produced by charges accelerating through space.
- Accelerating charges are the source of all Electromagnetic Radiation.
- The accelerating charges create a constantly changing electric field that travels away from the source in 3 dimensions. The continuously changing electric field then induces a changing magnetic field that is perpendicular to the electric field. The changing magnetic field in turn produces an electric field.
- Electromagnetic waves are created by oscillating magnetic and electric fields that move at right angles to each other and to the direction of the propagation of the wave.




**WAVE EQUATION (EM)**

The wave is propagated at a speed of $3\times10^8$ m·s$^{-1}$. This is called c (speed of light).
All electromagnetic waves travel at the speed of light.




**Conversions Table**

| Unit | Symbol | Unit in metres |
|---|---|---|
| Micrometres | $\mu$m | $10^{-6}$ |
| Nanometres | Nm | $10^{-9}$ |
| Picometres | Pm | $10^{-12}$ |

**EXAMPLE 1**

Determine the wavelength of ultraviolet waves with a frequency of $1{,}6\times10^{16}$ Hz

$c=f\lambda$✓

$3\times10^{8}=(1{,}6\times10^{16})\lambda$✓

$\lambda=1{,}88\times10^{-8}$ m✓

**EXAMPLE 2**

Determine the energy of the gamma ray with a wavelength of $4\times10^{-14}$ m.

$E = \frac{hc}{\lambda}$✓

$E=\frac{(6{,}63\times10^{-34})(3\times10^{8})}{(4{,}5\times10^{-14})}$ ✓

$=4{,}42\times10^{-12}$ J✓

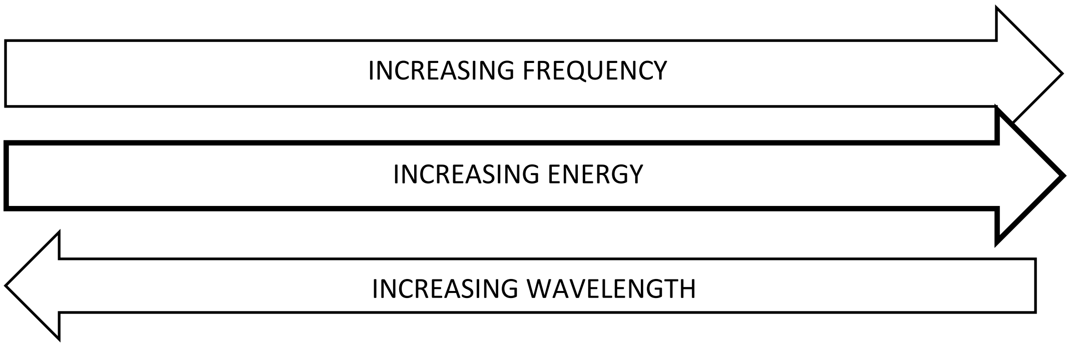
**PENETRATING ABILITY**

- The penetrating ability of a wave refers to its ability to move through matter.
- The higher the energy, the greater the penetrating ability.

penetrating ability α Energy

penetrating ability α Frequency

**ELECTROMAGNETIC RADIATION- SPECTRUM**




| EM Radiation: | Radio waves | Microwaves | Infrared radiation (IR) | Visible light<br>R \| O \| Y \| G \| B \| I \| V | Ultraviolet light (UV) | X-rays | Gamma rays |
|---|---|---|---|---|---|---|---|
| Frequency (Hz): | 1 x $10^{6}$ | 1 x $10^{10}$ | 1 x $10^{12}$ | 4 x $10^{14}$ to 7 x $10^{14}$ | 1 x $10^{16}$ | 1 x $10^{19}$ | 1 x $10^{22}$ |
| Wavelength (m): | 1 x $10^{2}$ | 1 x $10^{-2}$ | 1 x $10^{-4}$ | 7 x $10^{-9}$ to 4 x $10^{-9}$ | 1 x $10^{-8}$ | 1 x $10^{-10}$ | 1 x $10^{-14}$ |
| Advantages: | Radio and TV broadcasts; radio telescopes | Telephone and cell phone connections; communication satellites; microwave ovens; radar systems | Remote controls; optical fibers | Objects reflect, refract or transmit light that we are able to see; photosynthesis | Light bulbs; sterilization | x-rays; CT scans; security scans | Radiation of cancer |
| Disadvantages: | | | | | Damage to eyes and skin | Damage to skin and underlying tissue | Damage to tissue; nuclear radiation |

| Category | Uses |
|---|---|
| Gamma rays | Used to kill the bacteria in marshmallows and to sterilise medical equipment |
| X – rays | Used to image bone structures |
| Ultraviolet light | Bees can see into the ultraviolet because flowers stand out more clearly at this frequency |
| Visible light | Used by humans to observe the world |
| Infrared | Night vision, heat sensors, laser metal cutting |
| Microwave | Microwave ovens, radar |
| Radio waves | Radio, television broadcasts |

**QUESTION 1**

1.1 From the following, the electromagnetic wave with the longest wavelength is…

A Infrared
B Ultraviolet
C Microwave
D Visible light (2)

1.2 The method of detecting the presence, position, and direction of motion of distant objects by reflecting a beam of sound waves is known as …

A RADAR
B SONAR
C MIR
D CRO (2)

1.3 How does the speed of visible light compare with the speed of gamma rays when both speeds are measured in a vacuum?

A The speed of visible light is greater.
B The speed of gamma rays is greater.
C The speeds are the same.
D The speed of visible light is $3 \times 10^{-8}$ $m.s^{-1}$ (2)

**QUESTION 2**

The electromagnetic spectrum includes microwaves, ultraviolet light, gamma rays, and visible light.

2.1 Briefly describe the propagation of electromagnetic radiation through space. (3)
2.2 Arrange the four types of EM radiation listed above in order of increasing frequency. (2)
2.3 Which of the types of EM radiation listed above has the lowest penetrating power? (1)
2.4 Name **TWO** other types of EM radiation. (2)
2.5 A photon is emitted from an atom with an energy of $4.25 \times 10^{-19}$ J. What is the wavelength of the photon? (4)

**[12]**

**QUESTION 3**

The frequency and corresponding energy of electromagnetic waves are given in the table below.

| WAVE | FREQUENCY (Hz) | ENERGY (J) |
|---|---|---|
| **A** | **$2\times10^{9}$** | **$1{,}33\times10^{-24}$** |
| **B** | **$4\times10^{12}$** | **$2{,}65\times10^{-21}$** |
| **C** | **$3{,}5\times10^{15}$** | **$2{,}32\times10^{-18}$** |
| **D** | **$1{,}8\times10^{18}$** | **$1{,}19\times10^{-15}$** |
| **E** | **f** | **$4{,}97\times10^{-14}$** |

3.1 Describe how an electromagnetic wave propagates. (2)
3.2 What is the relationship between frequency and energy of an electromagnetic wave, as shown in the table above? (2)

3.3 Calculate the:

3.3.1 Frequency of wave **E** (3)

3.3.2 Wavelength of wave **D** (3)

3.4 Which wave, **A** or **B,** has the higher penetrating ability? Give a reason for the answer. **(Relationship between Frequency and Energy)** (2)

[12]

**QUESTION 4**

4.1 Consider the information below.

| **Electromagnetic (EM) wave** | **Wavelength (m)** |
|---|---|
| Gamma rays | $3 \times 10^{-11}$ |
| radio | $3 \times 10^{9}$ |

4.1.1 Which **ONE** of the two EM radiations has a higher penetrating ability? (1)

4.1.2 Mention **ONE** use of gamma rays. (1)

4.2 Consider the **ENTIRE** EM spectrum and state which of the EM radiations:

4.2.1 is most likely to cause skin cancer. (1)

4.2.2 is used to detect a fracture in a bone. (1)

4.2.3 is used for television broadcasts. (1)

4.3 Determine the amount of energy associated with a photon of a radio wave. (3)

**[8]**

**QUESTION 5**

5.1 The Sun produces electromagnetic radiation. The electromagnetic spectrum is shown in order of increasing wavelength. Two radiations P and Q have been omitted.

Wavelength increases →

| | | | | | | |
|---|---|---|---|---|---|---|
| Gamma rays | X rays | P | Visible light | Q | Microwaves | Television and radio rays |

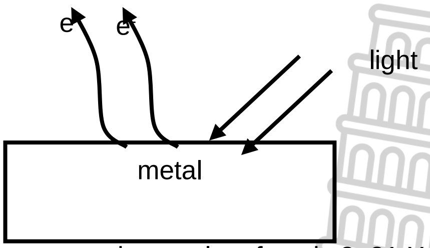
5.1.1 Identify P and Q. (2)

5.1.2 Which of the radiations has the lowest energy? Give a reason. (2)

5.1.3 Mention one property of gamma rays. (1)

5.1.4 What is the speed of electromagnetic waves in air? (1)

5.2 When light of a particular frequency is shone on a metal surface, it ejects electrons from the metal surface.




If the energy required to remove an electron from a certain metal surface is $3,31 \times 10^{-20}$ J, calculate the smallest frequency of a light ray that will be needed to remove the electron from this metal. (4)

**[10]**

**SOLUTIONS: WAVES, SOUND AND LIGHT (EM)**

**QUESTION 1**

1 1.1 C✓✓ (2)
1.2 B✓✓ (2)
1.3 C✓✓ (2)
**[6]**

**QUESTION 2**

2.1 A changing/ oscillating electric field induces a changing magnetic field ✓in the perpendicular plane✓, which induces a changing electric field. ✓ (3)
2.2 microwaves, visible light, ultraviolet light and. gamma rays ✓✓ (2)
2.3 microwaves ✓ (1)
2.4 X- rays, radio waves, infrared, (any two) ✓✓ (2)
2.5 $E = \frac{hc}{\lambda}$ ✓ (4)

$4,25 \times 10^{-19} = \frac{6,63 \times 10^{-34}\ (3 \times 10^{8})}{\lambda}$ ✓✓

$\lambda = 4,68 \times 10^{-7}$ m ✓
**[12]**

**QUESTION 3**

3.1 They propagate as an electric field and magnetic field perpendicular to each other. ✓✓ (2)
3.2 Energy is directly proportional to the frequency ✓✓ (2)

3.3 3.3.1 E=hf ✓ (3)

$4.97 \times 10^{-14} = 6.63 \times 10^{-34}$ f ✓

f= $7.496 \times 10^{19}$ Hz ✓

3.3.2 $E = \frac{hc}{\lambda}$ ✓ (3)

$1.19 \times 10^{-15} = \frac{6,63 \times 10^{-34}\ (3 \times 10^{8})}{\lambda}$ ✓

$\lambda = 1.667 \times 10^{-10}$ m ✓

OR

$c = f\lambda$✓

$3 \times 10^{8} = 1.8 \times 10^{18}\ \lambda$✓

$\lambda = 1.667 \times 10^{-10}$ m✓

3.4 B, ✓ higher frequency and higher enery✓ (2)
**[12]**

**QUESTION 4**

4.1 4.1.1 gamma rays✓ (1)
4.1.2 to kill cancer cells (1)
to sterilize medical equipement (any one ✓)
4.2 4.2.1 ultraviolet ✓ (1)
4.2.2 X-rays ✓ (1)
4.2.3 radio waves ✓ (1)
4.3 E = hf ✓ (3)
$= 6,63 \times 10^{-34}\ (1 \times 10^{8})$ ✓
$= 6,63 \times 10^{-26}$ J ✓
**[8]**

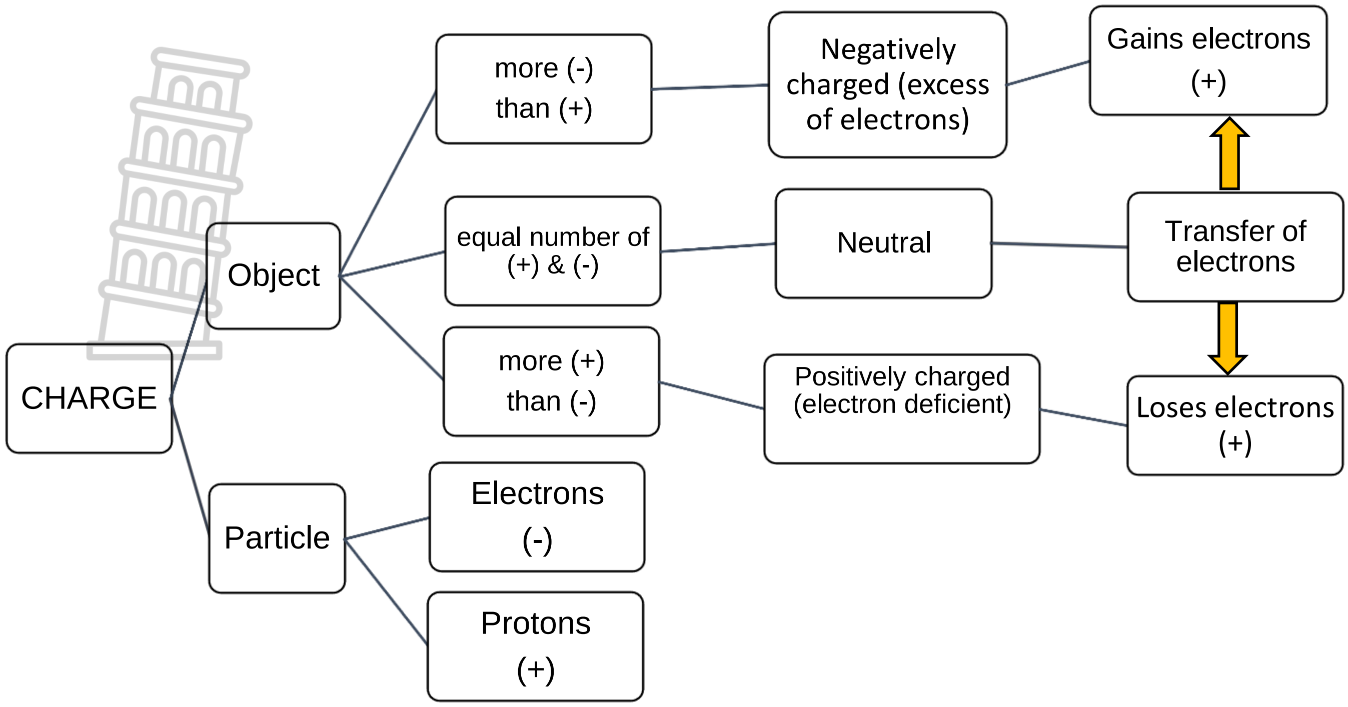
**QUESTION 5**

5.1 5.1.1 P: Ultraviolet ✓ (2)
Q: Infrared ✓
5.1.2 Radio waves, ✓ it has a lower frequency (any one ✓) (2)
5.1.3 Higher penetrating ability ✓ (1)
5.1.4 $3 \times 10^{8}$ $m.s^{-1}$ ✓ (1)

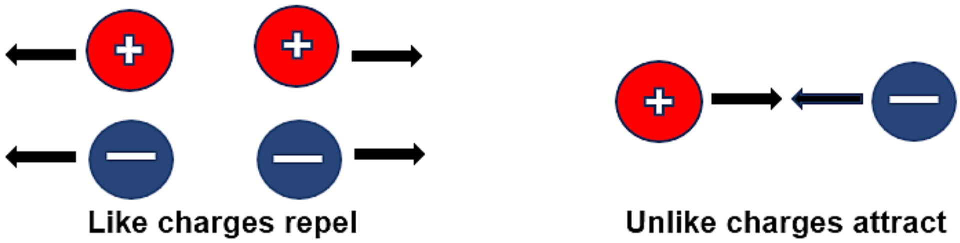
5.2 E = hf ✓ (4)
$3.31 \times 10^{-20}$ ✓= $6,63 \times 10^{-34}$ f ✓
f= $4.992 \times 10^{13}$ Hz✓
**[10]**

**ELECTROSTATICS (GRADE 10)**

Electrostatics is study of charges at rest



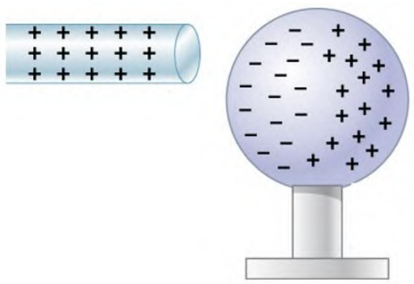

**Two kinds of charge**



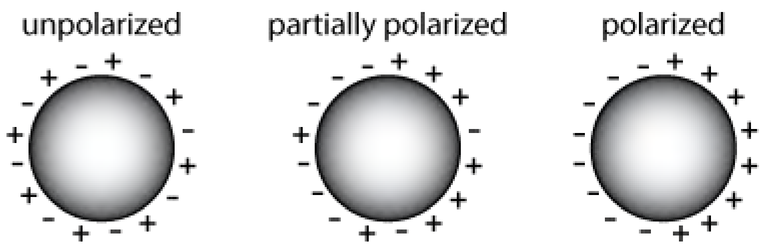

Objects become charged when electrons are either removed or added to them. This can be done by rubbing two materials together, called tribo-electric charging.

**Tribo-electric charging:** A type of contact electrification in which certain materials become electrically charged after they encounter different materials and are then separated (such as through rubbing)

Charged objects can attract uncharged objects because of the polarisation of molecules inside the object.



**Polarisation:** The partial or complete polar separation of positive and negative electric charge in a system.



**Charge conservation**

- SI unit for electric charge is the coulomb (C)
- Principle of conservation of charge: The net charge of an isolated system remains constant during any physical process.
- During contact, electrons are transferred from the more negative object to the less negative object until both objects have the same charge.
- $Q = \frac{Q_1+Q_2}{2}$

**Charge quantization**

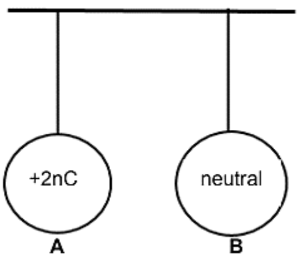
- principle of charge quantization: All charges in the universe consist of an integer multiple of the charge on one electron.
- $Q = nq_e$
- The charge on one electron ($q_e$) is called the elementary charge ($q_e = 1,6 \times 10^{-19}$ C).

**Conversion scale**

1 milli-Coulomb (mC) = 1 x $10^{-3}$ C
1 micro-Coulomb (μC) = 1 x $10^{-6}$ C
1 nano-Coulomb (nC) = 1 x $10^{-9}$ C
1 pico-Coulomb (pC) = 1 x $10^{-12}$ C

**WORKED EXAMPLE 1**

Two identical insulated spheres, A and B, suspended by a light inextensible string from a ceiling, are held a distance apart, as shown below.




Sphere A carries a charge of + 2nC, while sphere B is neutral.

1.1 Explain what is meant by neutral object. (2)

Sphere A is brought near the neutral sphere B and the spheres are allowed to touch each other. Immediately after touching, sphere B moves away from sphere A. Sphere B now has an excess of 20 electrons.

1.2 State the principle of conservation of charge in words. (2)
1.3 Briefly explain how the neutral sphere B is attracted to sphere A. (2)
1.4 Calculate the magnitude of the charge of sphere B. (3)
1.5 Calculate the charge on each sphere after they have separated. (3)

**[12]**

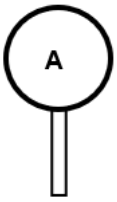
**SOLUTIONS**

1.1 Neutral charge – an atom that has equal number of electrons and protons. ✓✓ (2)
1.2 The net charge of an isolated system remains constant during any physical process. ✓✓ (2)
1.3 Due to polarisation, a negative charge is developed on the side of sphere B near sphere A and a positive charge is developed on the side of sphere B that is away from sphere A ✓. Sphere B moves towards sphere A (attraction) as opposite charges attract. ✓ (2)
1.4 $Q = n.q_e$ ✓ (3)
$Q = 20 \times (-1,6 \times 10^{-19})$ ✓
$Q = -3,2 \times 10^{-18}$ C ✓
1.5 $Q_{new} = \frac{Q_1+Q_2}{2}$✓ (3)
$= \frac{(2\times10^{-9})+(-3,2\times10^{-18})}{2}$✓
$= 9,99 \times 10^{-10}$ C ✓

**[12]**

**WORKED EXAMPLE 2**

2.1 A small, metal sphere A carrying a charge of $+2 \times 10^{-9}$ C is placed on an insulated stand.




2.1.1 How does the number of electrons compare to the number of protons in sphere A? (1)

$10^{13}$ electrons are now added to sphere A

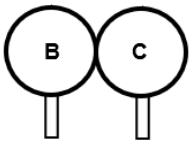
2.1.2 Calculate the new charge on sphere A (4)

2.2 Two identical metal spheres B and C placed on insulated stands, carry charges $+4 \times 10^{-6}$ C and $-6 \times 10^{-6}$ C respectively as shown in the diagram below.

The


spheres are allowed to touch each other.

After touching the




spheres are then separated and brought back to their original positions as shown in the diagram below.


2.2.1 State the principle of conservation of charge (2)

2.2.2 Calculate the number of electrons transferred between the two spheres during contact. (6)

**[13]**

**SOLUTIONS**

2.1.1 Less than ✓ (1)

2.1.2 $n = \frac{Q}{q_e}$ (4)

$10^{13}$✓$= \frac{Q}{-1,6 \times 10^{-19}}$ ✓

Q =-1,6 x $10^{-19}$ C

$Q_{new}$=(-1,6 x $10^{-19}$) + (2 x $10^{-19}$) ✓

= 4 x $10^{-20}$ C ✓

2.2.1 The net charge of an isolated system remains constant during any physical process. ✓✓ (2)

2.2.2 $Q_{new} = \frac{Q_1 + Q_2}{2}$✓ (6)

$= \frac{(4 \times 10^{-6}) + (-6 \times 10^{-6})}{2}$✓

= -1 x $10^{-6}$ C ✓

$$n = \frac{\Delta Q}{e}$$

$$n = \frac{Q_f - Q_i}{e}$$

$$= \frac{(-1 \times 10^{-6} - (-6 \times 10^{-6})✓}{1,6 \times 10^{-19}✓}$$

$= 3,13 \times 10^{13}$ electrons ✓

**[13]**

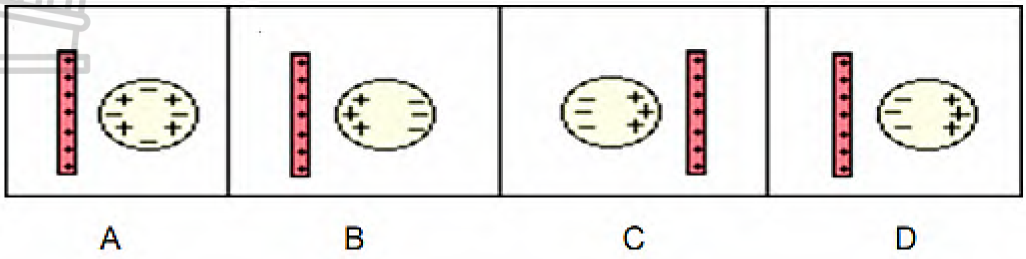
**ACTIVITIES**

**QUESTION 1 (MULTIPLE CHOICE)**

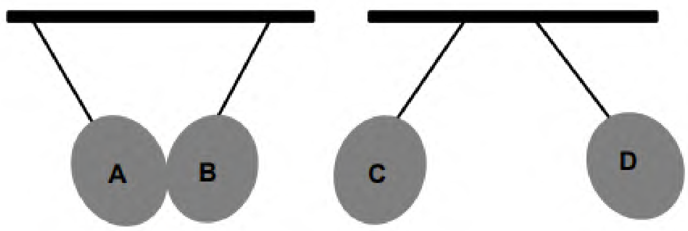
1.1. A neutral object has…

A no charges
B no imbalance in charge
C more neutrons than protons and electrons
D no electric field (2)

1.2. Which of the diagrams below best represents the charge distribution on a metal sphere when a positively charged plastic tube is placed nearby?




1.3 Four identical balloons, each carrying a charge, are suspended from a ceiling, as shown in the diagram below.




Balloon B is negatively charged.
Which combination is CORRECT regarding the charges on the balloons?

| | **SIGN OF CHARGE ON A** | **SIGN OF CHARGE ON C** | **SIGN OF CHARGE ON D** |
|---|---|---|---|
| A | - | + | - |
| B | + | + | + |
| C | - | - | - |
| D | + | + | - |

1.4 Two identical spheres, X and Y, on insulated stands, carry charges of 3 μC and -5 μC respectively. The spheres are brought into contact with each other and returned to their original positions. The charge on EACH sphere after contact is …

A -1 μC
B -2 μC
C -4 μC
D 8 μC (2)

1.5 A rubber balloon obtains a negative charge after it has been rubbed against human hair.

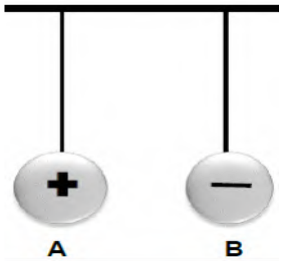
Which ONE of the statements below best explains why this happens?

A Negative charges are transferred from the rubber balloon to the human hair
B Positive charges are transferred from the rubber balloon to the human hair
C Positive charges are transferred from the human hair to the rubber balloon.
D Negative charges are transferred from the human hair to the rubber balloon. (2)

**[10]**

**QUESTION 2**

Two small, identical spheres A and B are suspended on long strings, as shown in the diagram below. The spheres carry charges of +5 x10$^{-9}$ C and -2 x10$^{-9}$ C respectively.




2.1 State the Principle of Conservation of Charge. (2)

The two spheres are brought into contact and then separated again

2.2 Which sphere, A or B, will gain electrons? Motivate the answer (2)

2.3 Calculate the:

2.3.1 Net charge of the two spheres during contact (2)

2.3.2 Charge on each sphere after separation. (3)

2.3.3 Number of electrons transferred during contact (4)

2.4 State what effect of each of the following changes will have of the magnitude of the electrostatic force. Write down only INCREASE, DECREASE or REMAIN THE SAME.

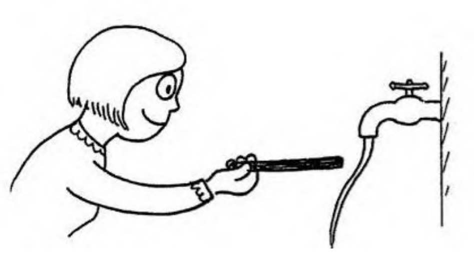
2.4.1 Increase the magnitude of the charges (2)

2.4.2 Bring the charges closer to each other. (2)

**[13]**

**QUESTION 3**

A learner in a Physical Sciences class rubs his hair with a plastic rod. The rod becomes negatively charged. The learner now opens a tap so that a thin stream of water runs from it. When the rod is brought close to the water without touching it, it is observed that the water bends toward the rod, as shown in the diagram below.



3.1 Write down the principle of quantisation of charge in words (2)

3.2 Give a reason why the stream of water bends towards the rod (2)

During the rubbing process 10$^{14}$ electrons are transferred to the rod.

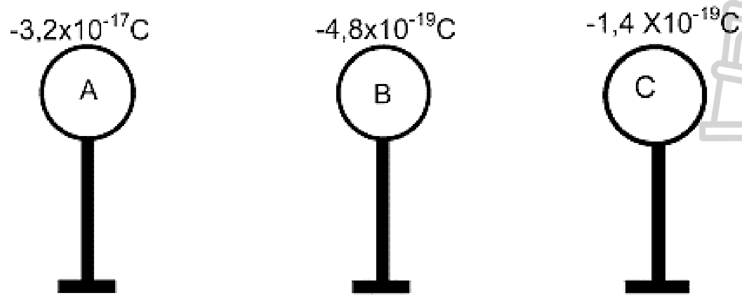
3.3 Calculate the net charge now carried by the rod. (4)

**[8]**

**QUESTION 4**

4.1 What is meant by triboelectric charging? (2)

4.2 Three metal spheres are placed on insulated stands and carry charges as shown below.

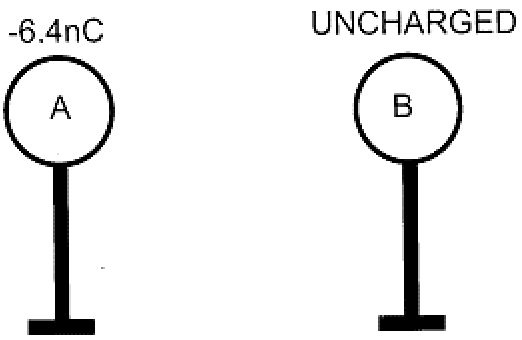



4.2.1 Determine the number of excess electrons found on sphere A. (3)

4.2.2 Is it possible for the charge indicated on sphere C to exist? State Yes or No. Give a reason for the answer. (2)

4.2.3 Name the principle used to explain your answer to question 4.2.2. (1)

4.3 Two identical metal spheres are placed on insulated stands as shown below.




Sphere A carries a charge of -6,4 nC and sphere B is UNCHARGED.

4.3.1 What is meant by sphere B is uncharged? (1)

Sphere A is now brought CLOSE to sphere B. The spheres DO NOT touch,

4.3.2 Draw a sketch to show the charge distribution that takes place on sphere B. (2)

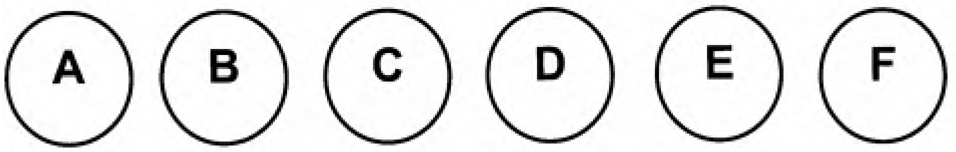
4.3.3 Name the phenomenon as described in question 4.3.2 (1)

The two spheres are now made to TOUCH each other, and they are then separated.

4.3.4 State the principle of Conservation of Charge. (2)

4.3.5 Calculate the new charge on each sphere after touching (3)

4.4 Refer to the six spheres A – F below. Sphere A is POSITIVELY charged. (5)
The charges on the other spheres are unknown.




A learner wishes to determine the nature of the charges on the other 5 spheres.
She makes the following observations:

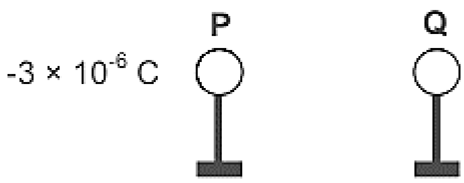
- F attracts both A and B
- D repels C
- E attracts D but repels F
- C attracts B

Use the above information to determine the nature of the charges on spheres B, C, D, E and F.

**[23]**

**QUESTION 5**

The diagram below shows two small identical spheres, P and Q, on insulated stands.
The charge on sphere P is -3 × 10-6 C and the charge on sphere Q is unknown.




5.1 Calculate the number of electrons in excess on sphere P. (3)

The two spheres are brought into contact and are then returned to their original positions. Each sphere now carries a charge of $-1 \times 10^{-6}$ C.

5.2 Calculate the original charge on sphere Q before the spheres were brought into contact. (3)

5.3 Were electrons transferred from P TO Q or from Q TO P during contact? (1)

**[7]**

**QUESTION 6**

Two identical pith balls are suspended on light, inelastic cotton threads. Pith ball A has a positive charge of 5,4 nC. Pith ball B carries a negative charge of 8,2 nC.

6.1.1 State the principle of quantization of charge. (2)

6.1.2 Calculate the number of extra electrons added to pith ball B. (4)

6.1.3 Two pith balls A and B are brought together, and then separated again to hang at the same original distance apart. Describe the type of force that pith ball B exerts on pith ball A. (1)

6.1.4 State the law of conservation of charge. (2)

6.1.5 Calculate the charge on pith ball B after it has touched pith ball A and is separated and hangs back at its original position. (3)

6.1.6 How many electrons were transferred from pith ball B to pith ball A when the pith balls touched each other? (4)

6.2 Explain each of the following phenomena using your knowledge of electrostatics

6.2.1 When the air is very dry, your hand feels a small sharp electric shock when you touch a metal doorknob after walking along the carpet to the door. (3)

6.2.2 When a charged plastic ruler is brought close to small pieces of paper the paper pieces are attracted to the ruler. (3)

**[22]**

**SOLUTIONS (ELECTROSTATICS GRADE 10)**

**QUESTION 1**

1.1 B ✓✓

1.2 D ✓✓

1.3 B ✓✓

1.4 A ✓✓

1.5 D ✓✓

**[10]**

**QUESTION 2**

2.1 The principle of conservation of charge states that the net charge of an isolated system remains constant during any physical process. ✓✓ (2)

2.2 A ✓ Electrons move from the negative sphere to the positive sphere ✓ or B has excess number of electrons or A has deficient number of electrons. (2)

2.3.1 $Q_{net} = Q_1 + Q_2$ (2)

$= + 5 \times 10^{-9} + (-2 \times 10^{-9})$ ✓

$= + 3 \times 10^{-9}$ C ✓

2.3.2 $Q_{new} = \frac{Q_1+Q_2}{2}$ ✓ (3)

$= \frac{(5\times10^{-9})+(-2\times10^{-9})}{2}$ ✓

$= +1{,}5 \times 10^{-9}$ C ✓

2.3.3 (4)

$n = \frac{Q_f - Q_i}{e}$ ✓

$= \frac{1{,}5\times10^{-9} - (-2\times10^{-9})✓}{1{,}6\times10^{-19}✓}$

$= 2{,}19 \times 10^{10}$ electrons ✓

OR

$n = \frac{Q_f - Q_i}{e}$ ✓

$= \frac{1{,}5\times10^{-9} - (5\times10^{-9})✓}{-1{,}6\times10^{-19}✓}$

$= 2{,}19 \times 10^{10}$ electrons ✓

2.4.1 Increase ✓✓ (2)

2.4.2 Increase ✓✓ (2)

**[17]**

**QUESTION 3**

3.1 The principle of charge quantization states that all charges in the universe consist of an integer multiple of the charge on one electron. ✓✓ (2)

3.2 The water molecule has a positive charge✓ and is attracted toward the rod ✓ OR Unlike charges attract ✓. The positive end of the water molecules are attracted ✓ to the negatively charged comb. OR The positive end ✓ of the water molecules are attracted ✓to the negatively charged rod. (2)

3.3 Q = nqe✓ (4)

$=10^{14}$ ✓x $(1{,}6 \times 10^{-19})$ ✓

$= 1{,}6 \times 10^{-5}$ C ✓

**[8]**

**QUESTION 4**

4.1 Process by which objects are charged by contact / rubbing ✓✓ (2)

4.2.1 $n = \frac{Q}{q_e}$ ✓ (3)

$= \frac{(-3{,}2\times10^{-17})}{-1{,}6\times10^{-19}}$✓

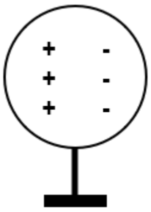
$= 200\ e^-$ ✓

4.2.2 No. ✓ the smallest charge that can exist is $1{,}6 \times 10^{-19}$ C ✓ (2)

4.2.3 Principle of Charge Quantization ✓ (1)

4.3.1 The number of electrons equals the number of protons ✓✓ (2)

4.3.2 (2)




✓✓

4.3.3 Charge Polarisation ✓ (1)

4.3.4 The net charge of an isolated system remains constant during any physical process. ✓✓ (2)

4.3.5 $Q_{new} = \frac{Q_1+Q_2}{2}$ ✓ (3)

$= \frac{(-6,4 \times 10^{-9})+0}{2}$ ✓

$= -3,2 \times 10^{-9}$ C ✓

4.4 B: neutral ✓ (5)

C: positive ✓

D: positive ✓

E: negative ✓

F: negative ✓

**[23]**

**QUESTION 5**

5.1 $n = \frac{Q}{q_e}$ ✓ (3)

$= \frac{(3\times10^{-6})}{1,6\times10^{-19}}$ ✓

$= 1,88 \times 10^{13}$ ✓ electrons

5.2 $Q_{new} = \frac{Q_1+Q_2}{2}$ ✓ (3)

$-1 \times 10^{-6} = \frac{(-3\times10^{-6})+Q_Q}{2}$ ✓

$Q_Q = 1 \times 10^{-6}$ C ✓

5.3 P to Q ✓ (1)

**[7]**

**QUESTION 6**

6.1.1 The principle of charge quantization states that all charges in the universe consist of an integer multiple of the charge on one electron. ✓✓ (2)

6.1.2 $n = \frac{Q}{q_e}$ ✓ (4)

$= \frac{(-8,2\times10^{-9})}{-1,6\times10^{-19}}$ ✓✓

$= 5,13 \times 10^{10}$ electrons ✓

6.1.3 Electrostatic force (repulsion) ✓ (1)

6.1.4 The net charge of an isolated system remains constant during any physical process. ✓✓ (2)

6.1.5 $Q_{new} = \frac{Q_1+Q_2}{2}$ ✓ (3)

$= \frac{(5,4\times10^{-9})+(-8,2\times10^{-9})}{2}$ ✓

$= -1,4 \times 10^{-9}$ C ✓

6.1.6 $n = \frac{Q}{q_e}$ ✓ (4)

$= \frac{(-1,4\times10^{-9})-(-8,2\times10^{-9})}{1,6\times10^{-19}}$ ✓✓

$= 5,13 \times 10^{10}$ electrons ✓

6.2.1 Electric charges are carried by electrons. When we shuffle our feet on the carpet, we are rubbing electrons off the carpet and onto our body.✓ When we then touch a metal doorknob, the extra electrons are transferred from our body to the metal✓ making a spark. ✓ (3)

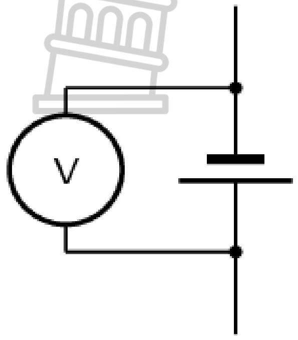
6.2.2 A plastic is an insulator which gets electrically charges when rubbed on hair.✓ It therefore attracts small bits of paper because paper gets polarized✓ in the presence of charged plastic ruler resulting in a net force of attraction✓ (3)

**[22]**

ELECTRIC CIRCUITS

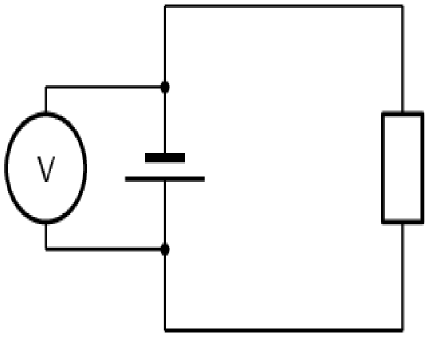
**Potential difference (V)**

- An electric current is a flow of charge, positive or negative.
- A battery supplies electrons to a circuit at its negative terminal and draws them in at the positive terminal by means of a chemical reaction in the battery. So, there is a onversion of chemical potential energy in the battery to electrical potential energy of the electrons.
- The voltage measured across the terminals of a battery when it is not providing current to a circuit is called the emf of the battery.




*Incomplete circuit/ open circuit*

- The voltage measured across the terminals of a battery when it is providing current to a circuit is called the potential difference across the circuit. This is alwaysbecausef, due to the fact that the battery has some resistance.

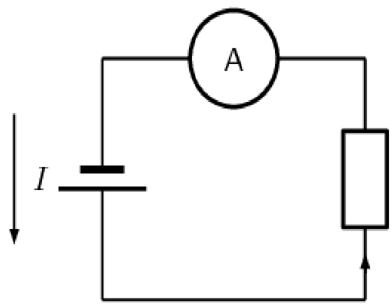



*Complete circuit*

- Emf and potential difference are measured in volts with a voltmeter, which has a very high resistance and is always connected in parallel across the circuit or resistor.

**Current**

- Current (I) is the rate of flow of charge.
- I = Q/Δt
- While an electric current can be a flow of negative or positive charge, direction of flow of charges is shown as the direction in which positive charge would move in the circuit (from positive to negative). This is referred to as '**conventional current'**.




- Current is measured in amperes (A). **1 ampere = 1 coulomb per second**

- **Definition of an ampere:** The current in a conductor is one ampere, when one coulomb of charge passes through the conductor per second.
- Current is measured with an ammeter, which has a very low resistance and is always connected in series.

**Resistance**

- Resistance (R) is the extent to which a resistor limits the flow of charge in it. When connected to the same potential difference, the higher the resistance of the resistor, he smaller the current.

- Resistance is measured in ohms (Ω).
- **Ohm's Law:** the current in a conductor is directly proportional to the potential Difference across it, provided its temperature remains constant.

$$V = IR$$

- **Definition of an ohm:** A resistor has a resistance of 1 ohm if it allows a current of 1 ampere when the potential difference across it is 1 volt. So, an ohm is a volt per ampere.
- **Factors affecting resistance:** Resistance depends on the type of metal, length, thickness, and temperature.
- A metal will have a higher resistance if its outer electrons are held more tightly by the nucleus of the atom. So, for instance, nichrome (an alloy of nickel and chromium) has a much higher resistance than copper.
- Current in metals is a flow of loosely bound electrons in the metal. The battery sets up an electric field in the circuit. The loosely bound electrons move under the action of this field. There is a conversion of electrical potential energy into kinetic energy of the moving electrons. The electrons collide with the atoms of the metal, causing them to vibrate faster. So, there is a conversion of kinetic energy of the electrons to vibrational kinetic energy of the atoms in the metal. The faster the atoms vibrate, the hotter they are. If very hot, they could give out light.
- **Energy conversions:**

Chemical potential energy in battery to electrical potential energy of electrons to kinetic energy of electrons to vibrational kinetic energy of atoms of metal to heat energy and possibly light energy.

- Resistance increases as the length of the resistor increases
- Resistance decreases as the thickness of the resistor increases.

This can be summarised as:

$$R \propto \frac{L}{A}$$

*Where* L *is the length and* A *is the cross-sectional area/thickness*.

- Resistance increases as the temperature of the resistor is increased.
- When a resistor is added in series to an identical one, the total resistance is doubled.
- When a resistor is added in parallel to an identical one, the total resistance is halved.

- To calculate the total resistance (equivalent resistance) $R_s$ of a number of resistors connected in series, simply add them together:

$Rs = R_1 + R_2 + R_3$ ……

- Current is the same at all points in a series circuit.
- Resistors in series divide the potential difference in proportion to the resistance. They are voltage dividers. Add the potential differences across each resistor together

to get the potential difference across the whole circuit.

- Resistors in parallel divide the current – they are current dividers. Add the currents together to get the mainstream current.

- The voltage across each resistor in a parallel connection is the same.

- To calculate the total resistance (equivalent resistance) Rp of a number of resistors in parallel, apply the formula:

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots +$$

After calculating the right-hand side of the equation, remember to invert both sides.

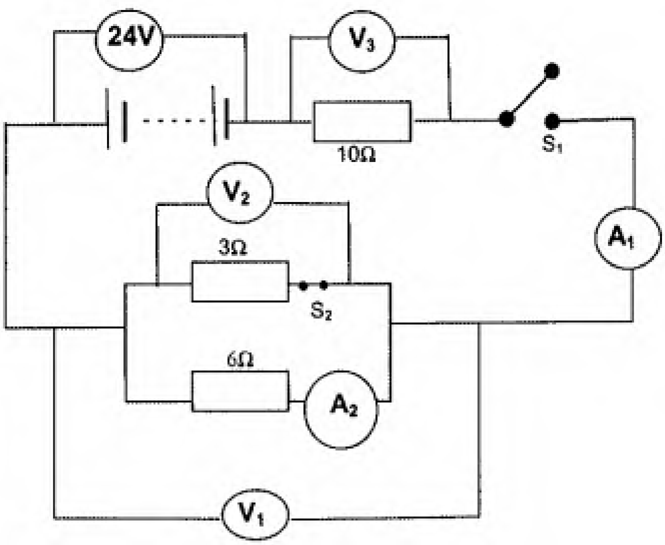
- For two resistors in parallel, the equation can be written as:

$$R_P = \frac{R_1 \, x \, R_2}{R_1 + R_2}$$

- Remember that the above equation can only be used for two resistors in parallel.

**Worked examples**

1. A battery is made of an unkown number of cells. Each of cells in the battery is labelled 3V. The battery is connected in a circuit as shown. Ignore the resistance of the of the battery and the wires. Initially switch $S_1$ is open and the voltmeter connected across the ends of the battery reads 24V




1.1 Does the reading of 24V represent emf or the terminal potential difference? Give a reason for your answer. (2)
1.2 Determine the number of cells in the battery? (1)
When switch $S_1$is now closed, the ammeter $A_1$reads 2A and $V_3$ reads 20V.
1.3 What will be the reading on:
1.3.1 $V_1$ (1)
1.3.2 $V_2$ (1)
1.4 What will the reading on $A_2$ be if 1.33A of current flows through the 3 Ω resistor? (1)
1.5 How many coulombs of charge flows through $A_1$ in 1 second? (1)
1.6 Calculate the total resistance in the circuit. (4)
1.7 How long (in minutes) will it take 4 800J of electrical energy to flow though the 10 Ω resistor? (5)
1.8 If switch $S_2$ is now opened (while $S_1$ remains closed) how will this affect the reading on $V_3$? Explain. (4)
(Choose from INCREASES, DECREASES or REMAINS THE SAME)

**[20]**

**SOLUTIONS**

1.1 Emf ✓
Since no current is flowing through the battery✓
1.2 8✓
1.3.1 4V✓
1.3.2 4V✓
1.4 0.67A✓
1.5 2C✓
1.6

$$\frac{1}{Rp} = \frac{1}{R_1} + \frac{1}{R_2} \quad ✓$$

$$\frac{1}{Rp} = \frac{1}{3} + \frac{1}{6} \quad ✓$$

$$Rp = 2\Omega \quad ✓$$

$$R_T = 12\Omega \quad ✓$$

1.7 $V = \frac{W}{Q}$ ✓

$20 = \frac{4800}{C}$ ✓

Q = 240 C

Q = IΔt ✓

240 = 2 x Δt ✓

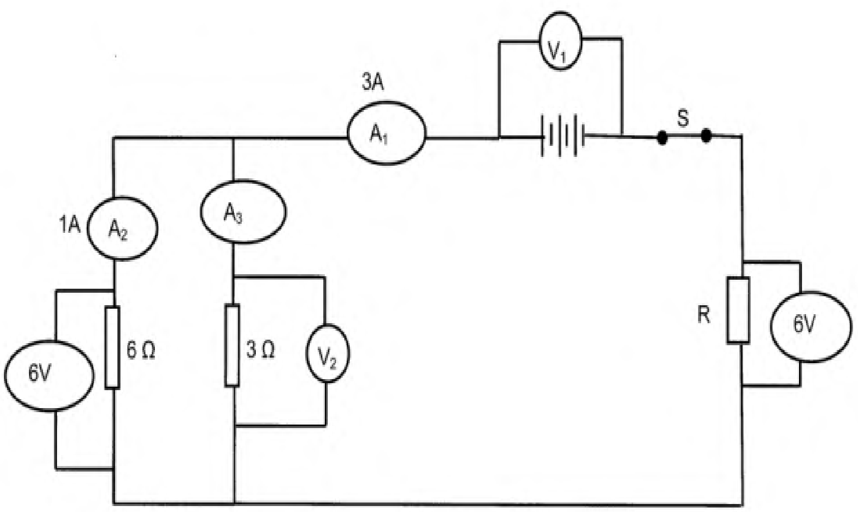
Δt = 120 s

= 2 minutes ✓

1.8 Apply Negative Marking

- Decreases ✓
- total resistance will increase✓
- causing total current to decrease✓
- which causes $V_3$ to decrease since $V_3 \propto I$✓

2. Study the circuit diagram below. The readings on ammeters Al and A2 are 3A and IA respectively. The voltmeters connected across the 6Q resistor and the resistor R both read 6V.




2.1 Define the term current strength. (1)

2.2 What is the reading on:

2.2.1 Ammeter A3? (1)

2.2.2 Voltmeter $V_2$? (1)

2.2.3 Voltmeter $V_1$? (1)

2.3 Calculate the effective resistance for the resistors connected in parallel. (3)

2.4 If the total resistance of the circuit is 4Q, determine the resistance of resistor R. (2)

2.5 Calculate the quantity of charge that flows through resistor R in 2 minutes. (3)

2.6 Determine how much electrical work will be done by the battery in 2 minutes. (3)

**Solutions**

2.1 The rate of flow of charge✓

2.2.1 2A✓

2.2.2 6V✓

2.2.3 12V✓

2.3 $\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$ ✓

$\frac{1}{Rp} = \frac{1}{6} + \frac{1}{3}$ ✓

$R_p = 2\ \Omega$✓

2.4 $R_T = R_p + R_R$

$4 = 2 + R$✓

$R_R = 2\ \Omega$✓

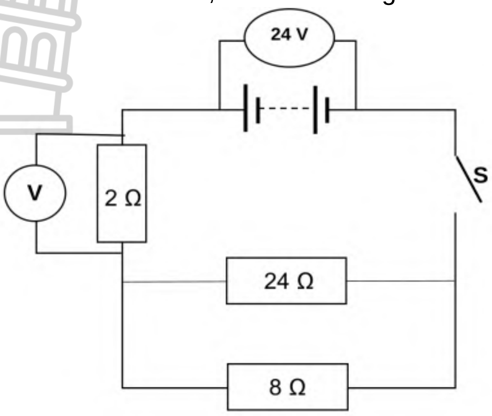
2.5 $I = \frac{Q}{t}$✓

$3 = \frac{Q}{120}$✓

Q = 360C✓

2.6 W = VQ✓
= 12x360✓
= 4320J✓

3. In the circuit below, the connecting wires and the battery have negligible resistance.




3.1 Define the term resistance. (2)

3.2 Calculate the:

3.2.1 Equivalent resistance of the resistors connected in parallel (3)

3.2.2 Total resistance of the circuit (2)

3.3 When the switch is closed, the voltmeter connected across the 2 Q resistor measures 6 V. Determine the potential difference across the parallel combination. (1)

3.4 A charge of 18 C flows through the battery in 6 s. calculate the current in the 2 Q resistor (3)

**Solutions**

3.1 The ratio of the potential difference across a resistor to the current in the resistor.✓✓

3.2.1 $\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$ ✓

$\frac{1}{Rp} = \frac{1}{24} + \frac{1}{8}$ ✓

$R_p$ = 6 Ω✓

3.2.2 $R_p = R_s + R_p$✓
= 2 + 6✓
= 8 Ω✓

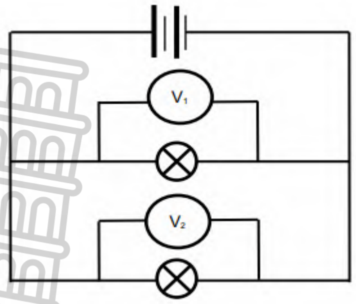
3.3 $V_p$ = 24V – 6V
=18V✓

3.4 Q = It✓
18 =I(6) ✓
I= 3A✓

**Multiple choice (MCQ)**

1. The UNIT in which the rate of flow of charge is measured, is called …
   A) Ampere
   B) Coulomb.
   C) Volt.
   D) Watt.

2. Two identical light bulbs are connected in parallel, as shown in the circuit diagram below. Voltmeters $V_1$ and $V_2$ are connected across each light bulb.




Which ONE of the following voltmeter readings is CORRECT?

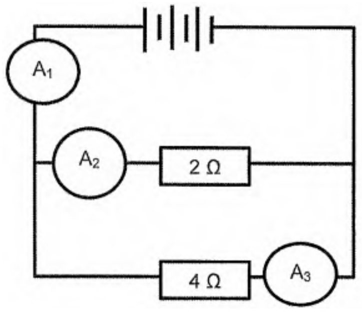
A) $V_1 = V_2$

B) $V_1 = 2V_2$

C) $V_1 = \frac{1}{2}V_2$

D) $V_1 = \frac{1}{4}V_2$ (2)

3. Consider the circuit diagram below.




How will the readings on ammeters $A_1$, $A_2$ and $A_3$ compare with each other?

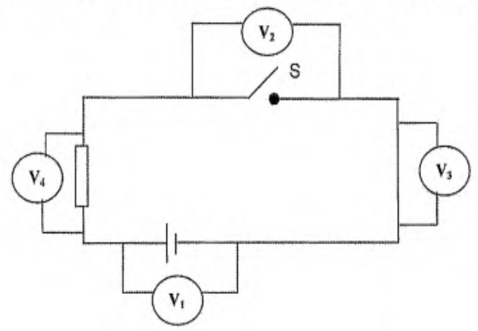
A) $A_1 = A_2 = A_3$

B) $A_1 = A_2 + A_3$

C) $(A_2 + A_3) > A_1$

D) $A_2 < A_3 < A_1$ (2)

**The following 2 questions refer to the circuit diagram below:**




4. When switch S is open, the reading on $V_1$ is 2V. which statement is correct with respect to the readings on the other voltmeters?

| | $V_2$ (V) | $V_3$ (V) | $V_4$ (V) |
|---|---|---|---|
| A | 2 | 2 | 2 |
| B | 0 | 0 | 2 |
| C | 2 | 0 | 0 |
| D | 0 | 0 | 0 |

(2)

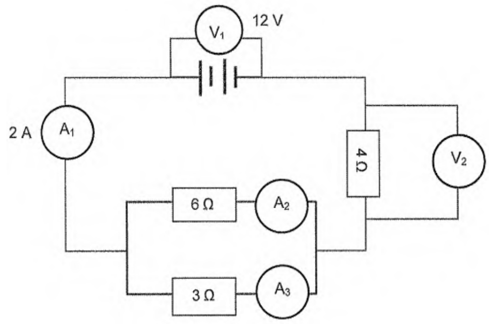
5. Switch S is now closed. The new readings on the voltmeters will be…

| | $V_2$ (V) | $V_3$ (V) | $V_4$ (V) |
|---|---|---|---|
| A | 0 | 0 | 2 |
| B | $^2/_3$ | $^2/_3$ | $^2/_3$ |
| C | 2 | 2 | 2 |
| D | 2 | 0 | 2 |

(2)

**Long questions**

1. In the circuit diagram below the reading on voltmeter $V_1$ is 12V and the reading on ammeter $A_1$ is 2A.




1.1 Calculate the:

1.1.1 Total resistance of the circuit. (4)

1.1.2 Reading on $V_2$. (3)

1.1.3 Reading on $A_2$ (3)

1.1.4 Amount of charge that flows through ammeter in $A_1$ in 120s (3)

1.2 How will the reading on ammeter $A_1$ be affected if the 6Ω resistor is removed from the circuit?

Write down only INCREASE, DECREASE or REMAIN THE SAME. (1)

1.3 Explain the answer to Question 1.2 without any calculations. (3)

2.

2.1 State one difference between emf and terminal potential difference? (2)

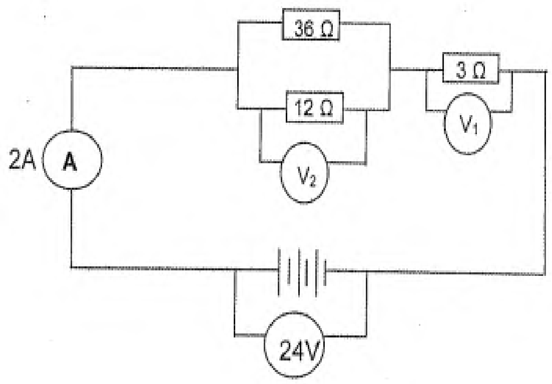
2.2 State Ohm's law in word. (2)

2.3 How will each of the following changes affect the resistance of a conductor? (choose from INCREASES, DECREASES or REMAINS THE SAME)

2.3.1 Heating the conductor. (1)

2.3.2 Increasing the cross-sectional area (thickness) of the conductor. (1)

2.4 Study the following circuit diagram and answer the questions set. The resistance of the battery and conducting wires may be ignored.




The ammeter reads 2A and $V_1$reads 6V.

2.4.1 Calculate the total resistance of the circuits. (5)

2.4.2 Calculate the quantity of charge that flows through the 3Ω resistor in 2 minutes? (3)

2.4.4 What is the reading on $V_2$. (2)

A third resistor is now added in parallel to the 36 Ω resistor. How will this affect each of the following? (choose from INCREASES, DECREASES or REMAINS THE SAME)

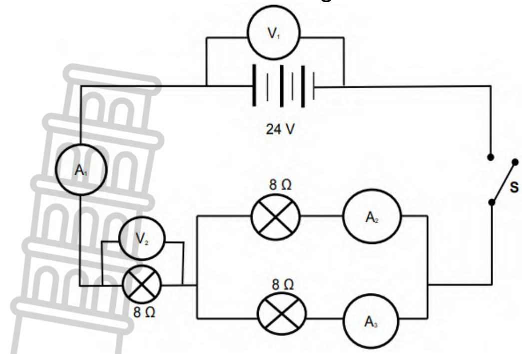
2.4.5 The reading on the ammeter. Explain the answer. (3)

2.4.6 The emf of the battery. Give a reason. (2)

**[24]**

3 

3.1 Consider the circuit diagram below.




Switch S is OPEN.

3.1.1 Write down the reading on the following:

a) Voltmeter (V1) (1)

b) Ammeter (A1) (1)

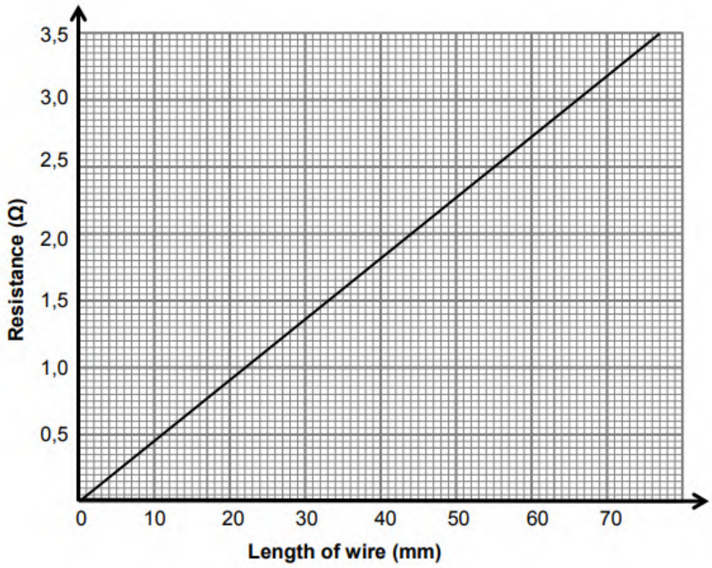
Switch S is now CLOSED.

3.1.2 Calculate the equivalent resistance of the circuit. (4)

3.1.3 Calculate the reading on voltmeter V2 (3)

3.1.4 How do the readings on ammeters A2 and A3 compare with each other? (1)

3.2 The graph below shows the relationship between the resistance and the length of the conducting wire.

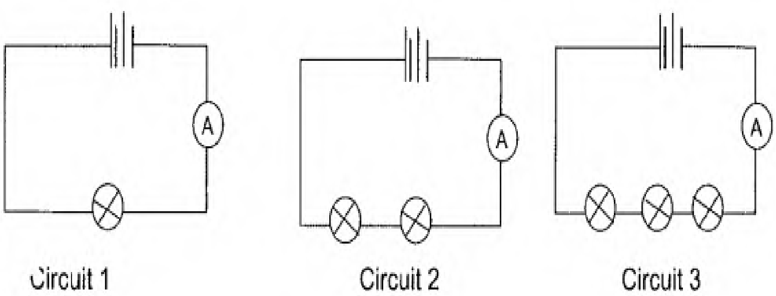



3.2.1 Write down the relationship between the resistance and the length of the conducting wire. (1)

3.2.2 Determine the resistance of wire with a length of 30 mm. (1)

**[12]**

4. Determine the resistance of wire with a length of 30 mm.




4.1 State the hypothesis that the learner wants to test. (2)

4.2 Identify the dependent variable. (1)

4.3 What energy conversion takes place in all 3 electrical circuits? (2)

**[5]**

**Solution**



**Multiple choice questions (MCQ)**

1 A✓✓
2 A✓✓
3 B✓✓
4 C✓✓
5 A✓✓

**Long questions**

1.1.1 $\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$ ✓

$\frac{1}{Rp} = \frac{1}{6} + \frac{1}{3}$ ✓

$R_p$ = 2 Ω

$R_{total}$ = 4 + 2 ✓

= 6 Ω✓

1.1.2 $R_{//} = R_{series}$

2 Ω : 4 Ω ✓

Therefore, potential difference is also in ratio of 2:4 or 1:2✓

Therefore 12V/3 parts =4V

$V_{series}$ = 2x4

= 8V ✓

1.1.3 $I = \frac{V}{R}$✓

$I = \frac{12-8}{6}$✓

= 0.67A✓

1.1.4 Q=It✓

= 2x120✓

= 240C✓

1.2 Decrease✓

1.3 If the 6 Ω resistor is removed, the resistance of the whole circuit increases.✓
Since R is inversely proportional to✓ if R increases, and V is constant then *I* of the circuit decreases.✓

2

2.1 Emf: voltage across the battery when no current is flowing. ✓

Terminal potential difference: voltage across the battery when current is flowing. ✓

2.2 the current in a conductor is directly proportional to the potential difference across it, provided its temperature remains constant.✓✓

2.3

2.3.1 Increase✓

2.3.2 Decrease✓

2.4.1 $\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$ ✓

$\frac{1}{Rp} = \frac{1}{36} + \frac{1}{12}$ ✓

$R_p$ = 9 Ω

$R_{total}$ = 9 + 3✓

= 12 Ω✓

2.4.2 Q = It✓

= 2x120✓

= 240C✓

2.4.3 V = VQ✓

=6x240✓

= 1440J✓

2.4.4 18V✓✓

2.4.5 Increase✓ -

More resistors in parallel create more pathways for current to flow. ✓

OR
Resistance of the circuit will decrease.✓
Current is inversely proportional to resistance.

2.4.6 Remains the same✓
-

Emf is constant.✓ It is the total amount of energy a cell gives to a quantity of charge passing through it.

3

3.1.1 a) $V_1$ = 24V✓
b) $A_1$ = 0 (A)✓

3.1.2 $\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$ ✓

$\frac{1}{Rp} = \frac{1}{8} + \frac{1}{8}$ ✓

$R_p$ = 4 Ω

$R_{total}$ = 8 + 4✓

= 12 Ω✓

3.1.3 V = IR
24 = I(12)
I = 2A

V =IR✓
= 2x8✓
=16V✓

3.1.4 $A_2 = A_3$ ✓

3.2.1 Resistance is directly proportional to the length of the conducting wire.✓
OR
As the length of the wire increases, the resistance increases.

3.2.2 1,35 Ω✓ (Range: 1,3 Ω to 1,4 Ω)

4.

4.1 As the number of resistors in series increases so will the current strength decrease ✓✓

4.2 Current strength ✓

4.3 Electrical energy converted to light/heat energy ✓✓

**MATTER AND ITS CLASSIFICATIONS**

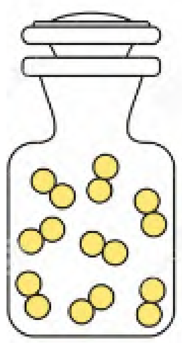
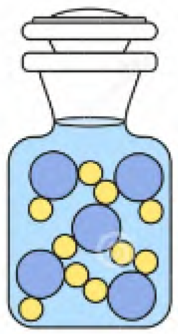
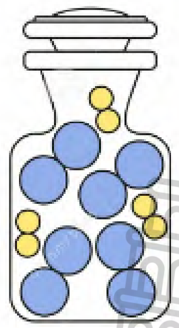
**THE MATERIAL(S) OF WHICH AN OBJECT IS COMPOSED**

- Materials can be divided into mixtures and pure substances
- Pure substances can be elements which consist of only one type of atom, or compounds which consist of more than one type of atom, bonded together in definite proportions.
- Elements can be metals, metalloids or non-metals.
- Metals are usually solids at room temperature. They are shiny, malleable and ductile and are good conductors of heat and electricity.
- Malleable substances can be hammered or pressed into shape without breaking or cracking.
- Ductile substances can be stretched into a wire.
- Non-metals are often gases at room temperature or soft or brittle elements. They are insulators of both heat and electricity.
- Metalloids have some properties of metals and some properties of non-metals.
- Magnetic materials are attracted by magnets. The only three magnetic elements are: iron, cobalt and nickel.
- Brittle substances are hard but likely to break easily.
- Density is the mass of a substance divided by its volume. Units are $g.cm^{-3}$.
- Boiling point of a substance is the temperature of a liquid at which its vapour pressure equals the external (atmospheric pressure).
- Melting point is the temperature at which a solid, given sufficient heat, becomes a liquid.

**Pure Substances: Elements and Compounds**

- Pure substances can be either elements or compounds
- Elements are pure substances which cannot be broken down into simpler substances by chemical methods.
- Compounds are pure substances made up of atoms of elements that are chemically combined in fixed ratios. Compounds contain more than one type of atom. They can be broken down into simpler substances by chemical methods.

Properties of Elements, Compounds and Mixtures

| **Elements** | **Compounds** | **Mixture** |
|---|---|---|
| Consist of one kind of atom | Composition is constant | Composition can vary and consists of two or more elements or compounds |
|  |  |  |

**Elements**

- Elements can be metals, non-metals or metalloids.
- Scientists use symbols to represent elements.
- Elements are made up of individual particles called atoms. The atom is the basic unit of matter

**Compounds**

- When two or more elements react compounds are formed.
- When carbon burns in oxygen for example, a compound called carbon dioxide is formed.
- The properties of carbon dioxide are different from those of oxygen and carbon.
- The formula of a compound tells us the elements which are found in that compound and the number of atoms of each element that are in each molecule or unit of the compound

The following table gives examples of compounds with their formulae:

| Compound | Formula | Elements making up the compound |
|---|---|---|
| Water | $H_2O$ | Hydrogen; Oxygen |
| Carbon dioxide | $CO_2$ | Carbon, Oxygen |
| Sodium nitrate | $NaNO_3$ | Sodium, Nitrogen, Oxygen |

**Metals, Metalloids and Non-metals**

- Substances can be classified as metals, metalloids and non-metals using their properties.
- Metals are found on the left hand side of the Periodic Table.
- Non-metals are found on the top right hand side of the Periodic Table
- Metalloids have properties of metals and non-metals.
- There are seven elements that are classified as metalloids on the Periodic Table and they are: boron, silicon, germanium, arsenic, antimony, tellurium and polonium.
- Metalloids have increasing conductivity with increasing temperature (the reverse of metals), e.g. silicon. Metals have decreasing conductivity with increasing temperature.

**Electrical Conductors, Semiconductors, and Insulators**

- Electrical conductors are materials that allow the flow of charge.
- Semiconductors are substances that can conduct electricity under some conditions, but not others, making them a good medium for the control of electrical current.
- Electrical insulator: A material that prevents the flow of charge.
- All materials fall under one of the following categories: electrical conductors, semiconductors or insulators.

**Thermal Conductors and Insulators**

- A thermal conductor is a material that allows heat to pass through easily, whilst a thermal insulator does not allow heat to pass through it.
- The following materials are examples of thermal insulators: Air, cork, wool rubber wood, polystyrene.
- The following materials are examples of thermal conductors: silver, copper, aluminium, steel.

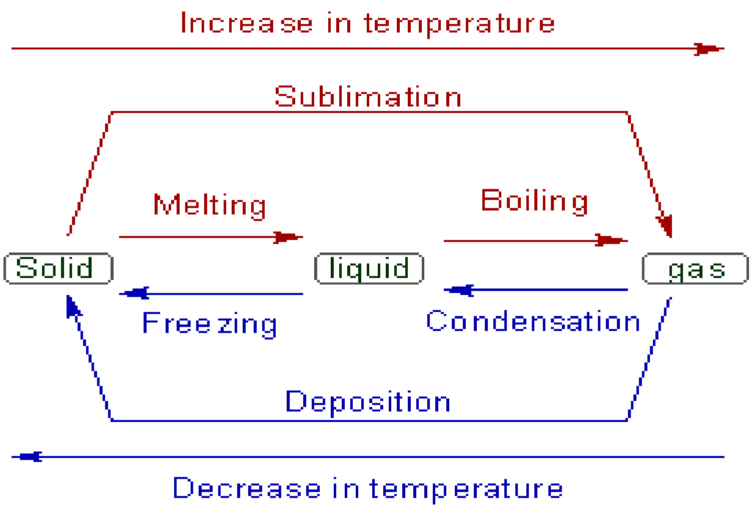
**State of matter and kinetic molecular theory**

- Matter consists of small particles.
- Particles of matter are in a constant state of random motion called Brownian motion.
- This random movement of microscopic particles suspended in a liquid or gas, caused by collisions between these particles and the molecules of the liquid or gas.
- Particles collide (with the sides of the container and with each other) and exert pressure
- Diffusion is the movement of atoms or molecules from an area of higher concentration to an area of lower concentration.
- Matter exists in any one of the following three states i.e. liquids, solids and gases
- Diffusion is the movement of atoms or molecules from an area of higher concentration to an area of lower concentration.
- The properties of the states are summarised in the following table:

| Solids | Liquids | Gases |
|---|---|---|
| Particles are bonded in fixed positions | Particles can move over one another | Particles are far apart |
| Strong forces between the particles | Forces between particles are weaker than in solids | Virtually no forces between particles |
| Small spaces between particles i.e. particle density is high | Spaces between particles slightly larger than in solids i.e. particle density is lower | Large spaces between particles i.e. particle density is very low |
| Particles vibrate in their fixed positions | Particles move about more vigorously | Particles move about at high speed. |

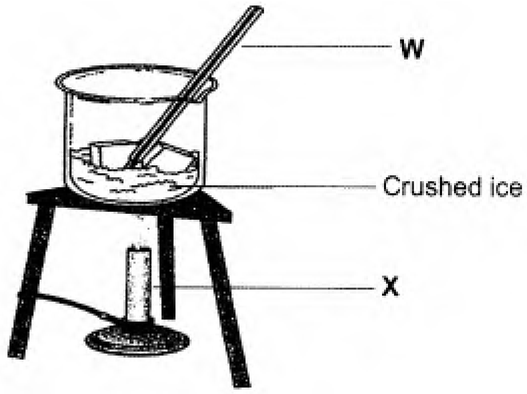
- Liquids and solids are called condensed states because particles are very close together.
- Liquids and gases are called fluids because particles can move past one another.
- Temperature is a measure of the average kinetic energy of a substance.
- A phase change may occur when the energy of particles changes
- Boiling point is the temperature at which the vapour pressure of a substance equals the atmospheric pressure
- Freezing point is the temperature at which a liquid changes to a solid by the removal of heat.
- Melting point is the temperature at which a solid, given sufficient heat, becomes a liquid.

- Melting is the process during which a solid changes to a liquid by the application of heat.
- Evaporation is the change of a liquid into a vapour at any temperature below the boiling point.
- Evaporation takes place at the surface of a liquid, where molecules with the highest kinetic energy are able to escape.
- When evaporation happens, the average kinetic energy of the liquid is lowered, and its temperature decreases.
- Freezing is the process during which a liquid changes to a solid by the removal of heat.
- Sublimation is the process during which a solid changes directly into a gas without passing through an intermediate liquid phase.
- Condensation is the process during which a gas or vapour changes to a liquid, either by cooling or by being subjected to increased pressure.




Worked Example:

1. Grade 10 learners conducted an experiment to determine the heating curve of water by using crushed ice at standard pressure, as shown in the figure below

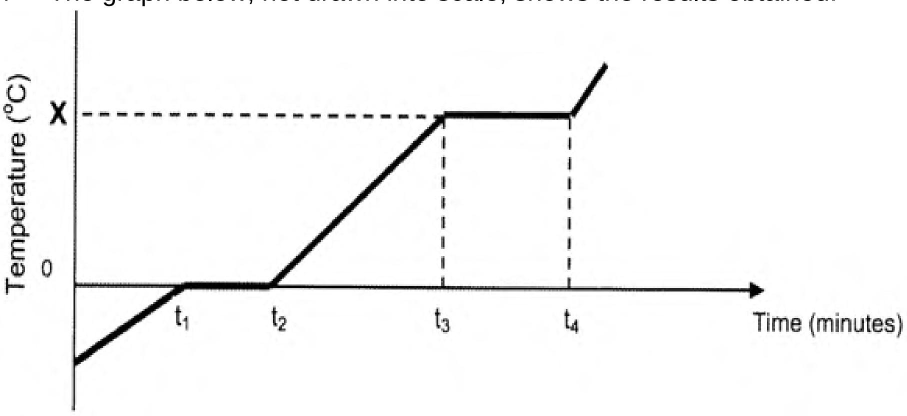



1.1 define the boiling point (2)

1.2 Write down the name of an instrument labelled W (1)

1.3 Explain why crushed ice was used instead of ice cubes? (2)

1.4 The graph below, not drawn into scale, shows the results obtained.



1.4.1 Write down the value represented by X. (1)
1.4.2 Name the predominantly phase of this substance between $t_2$ and $t_3$. (1)
1.4.3 Write down the process taking place between $t_3$ and $t_4$. (1)
1.4.4 Explain increase in temperature between $t_2$ and $t_3$. (2)
1.4.5 How will the above graph be affected if a larger quantity of crushed ice was used? (2)
[12]

Worked Example solutions

1.1 The temperature at which the vapour pressure of the substance equals theatmospheric pressure. ✓✓ (2)

1.2 Thermometer (1)

1.3 To allow uniform absorption of heat energy. ✓ (2)
For accurate measurement of temperature. ✓

1.4 1.4.1 $100°C$✓ (1)
1.4.2 Liquid✓ (1)
1.4.3 Boiling✓ (1)
1.4.4 The energy absorbed by liquid particles increases✓, particles vibrate vigorously the temperature rises. ✓ (2)
1.4.5 The crushed ice will take longer to reach phase change and boiling point✓✓ (2)
**[12]**

**Atomic structure**

- When one or more electrons are removed from an atom, the atom becomes positively charged (cation).
- When one or more electrons are added to an atom, it becomes negatively charged (anion).

**Isotopes**

- Isotopes are atoms of the same element having the same number of protons, but different numbers of neutrons.
- Relative atomic mass is the mass of a particle on a scale where an atom of carbon-12 has a mass of 12.

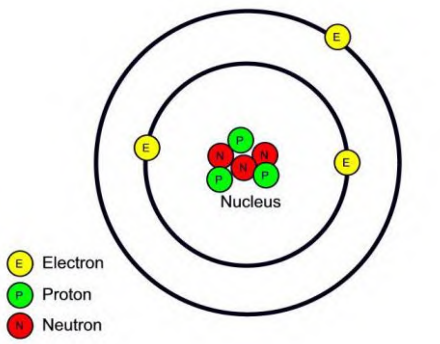
Example: Calculate the relative formula mass of calcium carbonate ($CaCO_3$).
Solution: $M_r(CaCO_3) = 40 + 12 + 3(16)$ ✓ $= 100g$. ✓

- The atomic number (Z) is the number of protons in the nucleus of an atom
- The mass number (A) is the number of protons and neutrons in the nucleus of an atom
- The notation $^{A}_{Z}E$ is used to represent an isotope of an element where E is the symbol of the element, Z is the atomic number and A is the mass number.

Example: write down the $^{A}_{Z}E$ notation of lithium
Solution: $^{7}_{3}Li$✓✓

**Electron configuration**

- The term electron configuration refers to the way that electrons are arranged around the nucleus.
- Electrons move around the nucleus in specific energy areas that are called energy levels.
- Atomic orbitals are the most probable regions in space where electrons that have the specific energy corresponding to the orbital are found.
- The arrangement of electrons, neutrons and protons of Lithium are shown below.




- The following rules are used in order to distribute electrons into energy levels
  - ➢ Energy levels are filled from the lowest energy to the highest energy (Aufbau Principle).
  - ➢ There can only be two electrons of opposite spin in any one orbital (this is called Pauli's exclusion principle).

- When there is more than one orbital of the same energy, each orbital must be filled singly before it can be occupied by two electrons (this is called Hund's rule).

- The electron configurations of a few elements are shown below:
  Hydrogen (H): $1s^1$
  Helium (He): $1s^2$
  Oxygen (O): $1s^2\ 2s^2\ 2p^4$
  Sodium (Na): $1s^2\ 2s^2\ 2p^6\ 3s^1$

Example: write down the SP notation for neon(Ne)
Solution: (Ne) $1s^2\ 2s^2\ 2p^6$

**The periodic-table of elements**
The positions of the elements in the periodic table related to their electronic arrangements

- The periodic table display the elements in order of increasing atomic number.
- The periodic table shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.
- Groups are the vertical columns in the periodic table.
- Some groups have names, e.g. alkali metals (group I), earth-alkaline metals (group 2), halogens (group 17) and noble gases (group18).
- Periods are the horizontal rows in the periodic table.
- The position of an element in the periodic table is related to its electronic structure and vice versa.
- Periodicity is the repetition of similar properties in chemical elements, as indicated by their positioning in the periodic table
- Moving from Li to Ne, properties of elements in terms of atomic radius, ionisation energy, electron affinity and electronegativity are repeated from Na to Ar.
- Atomic radius is the mean distance from the nucleus to the border of the outer orbital.
- Ionisation energy is the energy needed per mole to remove an electron(s) from an atom in the gaseous phase
- First ionisation energy is the energy needed per mole to remove the first electron from an atom in the gaseous phase.
- Electron affinity is the energy released when an electron is attached to an atom or molecule to form a negative ion
- Electronegativity is a measure of the tendency of an atom in a molecule to attract bonding electrons
- Metals are found on the left hand side of the periodic table
- Non-metals are found on the right hand side of the periodic table.
- Group 1 elements are called alkali metals. They form positive ions and they react strongly with oxygen and water.
- Group 2 elements are called alkaline-earth metals. They form positive ions with a +2 charge and they react with oxygen and water.
- Group 1 oxides are soluble in water but group 2 oxides are not.
- Group 17 elements are called halogens. They are the most reactive non-metals and they form an ion with a charge of -1.
- Group 18 elements are called noble gases and they are unreactive.
- In groups 1 and 2, chemical reactivity increases from top to bottom.
- In group 17, chemical reactivity decreases from top to bottom.
- Elements in the same group have the same number of electrons in their outer energy levels
- Elements in the same period have their outer electrons in the same energy level

**Chemical bonding**

- Define a chemical bond as a mutual attraction between two atoms resulting from the simultaneous attraction between their nuclei and the outer electrons.
- There are three types of chemical bonding:
  Non-metal + non-metal = covalent bond
  Non-metal + metal = Ionic bond
  Metal +metal = metallic bond
- The energy of the combined atoms is lower than that of the individual atoms resulting in higher stability.
- A Lewis dot diagram is a structural formula in which valence electrons are represented by dots or crosses. It is also known as an electron dot formula, a Lewis formula, or an electron diagram.

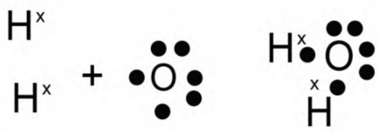
- The following are examples of Lewis structures of two elements:

Oxygen : 

Hydrogen: 

**Covalent bonding**

- A covalent bond is the sharing of electrons between atoms to form molecules
- A molecule is a group of two or more atoms that are covalently bonded and that functions as a unit.
- In a Lewis dot diagram two dots between atoms represent a covalent bond. These two electrons are known as a bonding pair, whilst non-binding electron pairs are called lone pairs.
- The formation of a covalent bond between two hydrogen atoms and one oxygen atom can be represented by means of Lewis structures as follows:




- The bonding pair of electrons between each hydrogen atom and the oxygen atom, are share by hydrogen and oxygen.

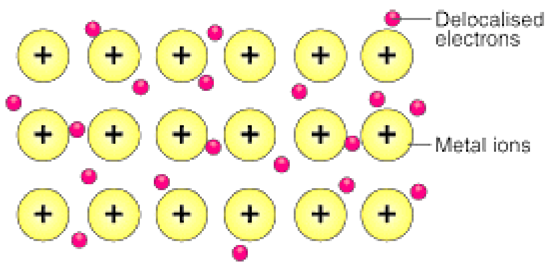
**Ionic bonding**

- Ionic bonding is the transfer of electrons to form cations (positive ions) and anions (negative ions) that attract each other to form a formula-unit
- The formation of an ionic bond between sodium and chlorine can be represented by means of Lewis structures as follows:


- A formula-unit is the simplest empirical formula that represents the compound.
- An ion is a charged particle made from an atom by the loss or gain of electrons
- A crystal lattice is an orderly three-dimensional arrangement of particles (ions, molecules or atoms) in a solid structure.
- In a crystal of sodium chloride each sodium ion is surrounded by six chloride ions to form a cubic structure. Each chloride ion is also surrounded by six sodium ions.

**Metallic bonding**

- Metallic bonding is the bond between positive ions and delocalised valence electrons in a metal.
- Valence electrons or outer electrons are the electrons in the highest energy level of an atom in which there are electrons.




**MATTER AND MATERIALS ACTIVITIES**

**Multiple-choice questions**

**Question 1**

1.1 The electron configuration of a neutral atom of an element X is $1s^2\ 2s^2\ 2p^3$. Which one of the following would be the electron configuration of $X^{3-}$?

A $1s^2\ 2s^2$

B $1s^2\ 2s^2\ 2p^6$

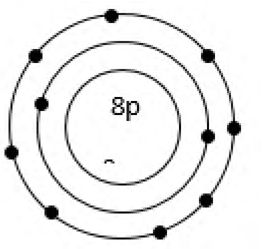
C $1s^2\ 2s^2\ 2p^3$

D $1s^2\ 2s^2\ 2p^0$ (2)

1.2 From which of these atoms in the ground state can a valence electron be removed using the least amount of energy?

A Nitrogen
B Oxygen
C Carbon
D Fluorine (2)

1.3 Which of the following does the Bohr model below represent?




A An atom of neon
B An ion of oxygen
C A molecule of oxygen
D A neutral atom of oxygen (2)

1.4 Covalent bonding involves the ____________ of electrons, while ionic bonding involves the ____________ of electrons.

A sharing; splitting
B exchanging; sharing
C sharing; transferring
D transferring; sharing (2)

1.5 A neutral atom of an element has an electron configuration of $1s^22s^22p^5$.
In which group and period of the periodic table is this element located?

A Group II, Period 7
B Group V, Period 2
C Group VII, Period 2
D Group VII, Period 5 (2)

1.6 Which of the following statements best describes the forces found in metallic lattices?

A Electrostatic forces between positive ions and electrons.
B Electrostatic forces between positive ions and negative ions.
C London forces between non-polar molecules.
D Hydrogen bonds between (2)

1.7 Which one of the following statements about the trends down Group VII (lowest to highest atomic number) in the Periodic Table is correct?

A The atomic size increases
B The ionisation energy increases
C The non-metallic character increases
D The number of valence electrons (2)

1.8 Consider the following elements:
potassium (K); zinc (Zn); phosphorous (P); antimony (Sb); argon (Ar)

Which of the following statements is true?

A All are metals.
B All are non-metals.
C All are chemically reactive.
D One is a metalloid (semi-conductor). (2)

1.9 What is the percent by mass of oxygen in $H_2SO_4$?
- A 16%
- B 33%
- C 65%
- D 98% (2)

[18]

**Question 2**

2.1 Differentiate between a thermal conductor and an electrical conductor. (2)

2.2 Differentiate between a thermal conductor and an electrical conductor.
glass; copper; sugar water; nickel; carbonated water; air; carbon dioxide
From the list above, identify:
- 2.2.1 A thermal conductor (1)
- 2.2.2 A magnetic material (1)
- 2.2.3 A heterogeneous mixture (1)
- 2.2.4 An electrical insulator (1)

**[6]**

**Question 3**

The grade 10 learners were investigating the effect of heat on ice, H2O(s). The Temperature was recorded every 5 minutes. The following results were obtained and Recorded in the table below.

| Time (min) | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| Temperature(°C) | -10 | 0 | 0 | 0 | 25 | 45 | 75 | 85 | 85 |

3.1 Define the term *boiling point*. (2)

3.2 Name the instrument used to measure the temperature of ice, H2O(s). (1)

3.3 Identify the independent variable. (1)

3.4 Draw the graph that represents the data providedin the table above. (5)

3.5 Name the process that water undergoes at the time between 35 and 40 minutes. (1)

3.6 Explain your answer to QUESTION 3.5 by referring to energy changes. (3)

[13]

**Question 4**

Consider Magnesium and Chlorine:

4.1 How many valence electrons does each atom have? (2)

4.2 Using Lewis Diagrams, show the formation of the cation and the anion when magnesium and chlorine bond chemically. (3)

4.3 What force keeps the ions together in the crystal lattice? (1)

4.4 In which ratio are the cations and anions found in the crystal lattice? (2)

4.5 Name this compound. (1)

**[9]**

**Question 5**

5.1 Describe the difference between atomic mass and relative atomic mass. (3)

5.2 The element potassium has three naturally occurring isotopes with the following abundance:

$^{39}K = 93{,}26\%$

$^{40}K = 0{,}2\%$

$^{41}K = 6{,}57\%$

Calculate the relative atomic mass of potassium. (4)

5.3 What is meant by an atomic orbital, and how does it differ from an orbit? (4)

5.4 Naturally occurring neon has three isotopes with following abundance:

$^{20}Ne = 90,48\%$

$^{x}Ne = 0,233\%$

$^{22}Ne = 9,25\%$

By means of a calculation, determine the mass number x, if the relative atomic mass of neon is 20,18 (5)

[16]

**Question 6**

Magnesium metal reacts readily with oxygen when it is burned in air.

6.1 Write down a word equation for the reaction of magnesium with oxygen. (3)

6.2 Write down the chemical formula for the substance formed in QUESTION 6.1 (2)

6.3 Write down the valence electron configuration for magnesium. (2)

6.4 Write down the valence electron configuration for oxygen. (2)

6.5 Write down the symbol for the cation formed when magnesium loses its valence electrons. (1)

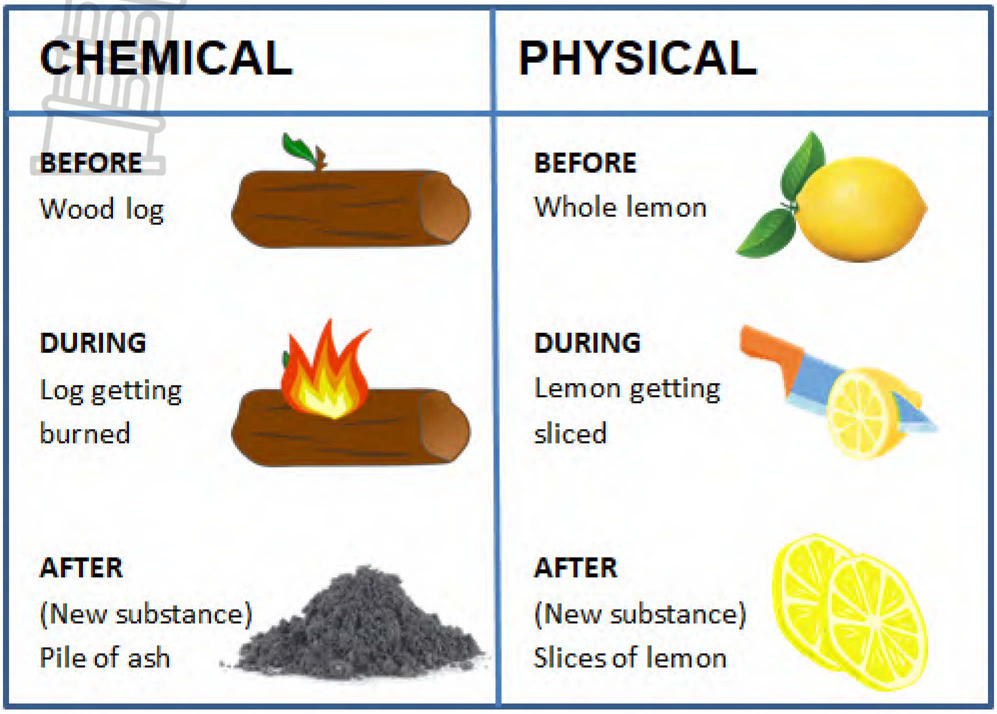
6.6 Write down the symbol for the anion formed when oxygen accepts two electrons into its valence shell (1)

[11]

## PHYSICAL AND CHEMICAL CHANGE

- **Physical change:** Involves a change in the phase of a substance e.g., from liquid to gas.
- **Chemical change:** Involves a change in the composition of a substance

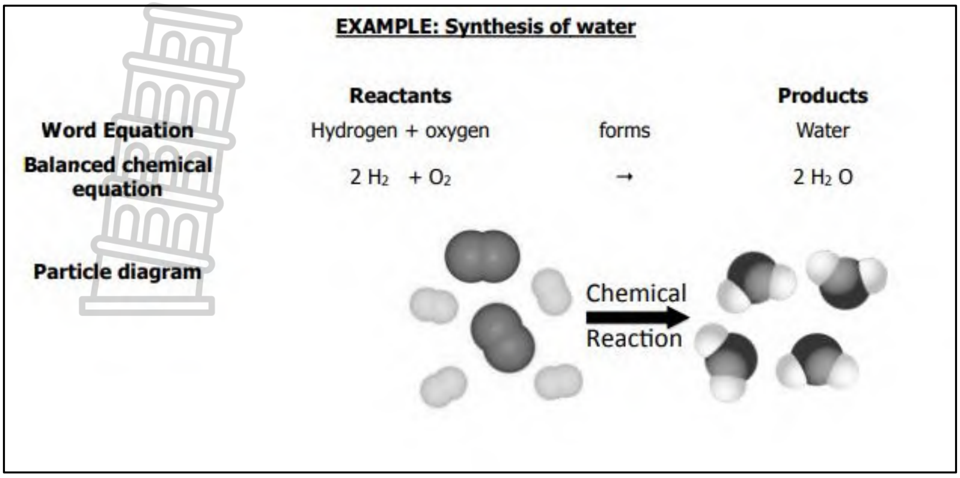
e.g. from hydrogen and oxygen gases to water vapour.



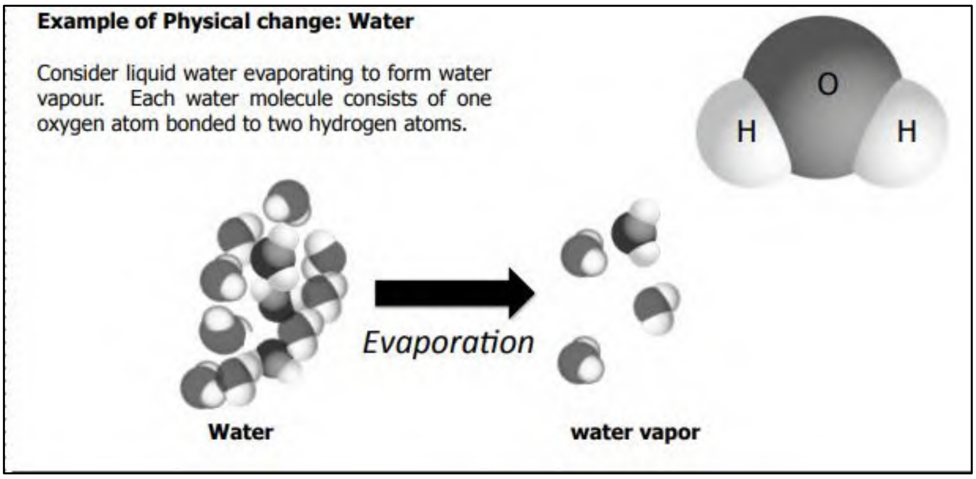

| | Physical Change | Chemical Change |
|---|---|---|
| Differences | No new substances are formed. | New substances are formed. |
| | Lower energy changes. | Higher energy changes. |
| | Mass, number of atoms and molecules are conserved. | Mass and number of atoms are conserved, but molecule numbers may change. |
| | Energy is released or absorbed during a PHASE change. | Energy is absorbed when chemical bonds are broken and it is released when chemical bonds are formed. |
| | Have no direct effect on chemical bonds or number of molecules | Have effect on the chemical bonds of molecules – chemical bonds are broken and new bonds are formed |
| Examples | Ice melting, salt dissolving in water, breaking glass into fragments, water evaporating into air, mixing oil with water | 1. hydrogen burns in oxygen to form water.<br>2. hydrogen peroxide decomposes into hydrogen and oxygen.<br>3. hydrochloric acid reacted with sodium hydroxide to form sodium chloride and water. |

Water can undergo chemical and physical changes as shown below.

CHEMICAL CHANGE




PHYSICAL CHANGE




**Representing Chemical Change**

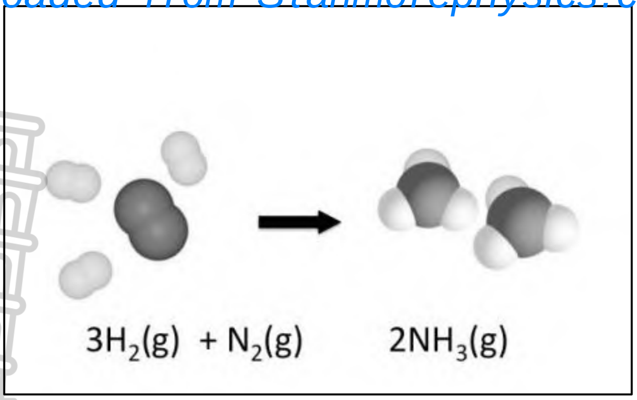
- Phases in a chemical reaction: (g) Gas; (s) Solid; (l) liquid; (aq) aqueous
  A typical aqueous solution involves ions dissolved in water.
  e.g. $Na^+$ and $Cl^-$ ions in water is referred to as $Cl^-_{(aq)}$ and $Na^+_{(aq)}$

- Word equations
  Sodium + water ⟶ sodium hydroxide + hydrogen
  Reactants — Products

- Symbolic representation
  $Na + H_2O \longrightarrow NaOH + H_2$

- Balancing the equation
  The number of atoms on the RHS should balance those on the LHS.
  $2Na + 2H_2O \rightarrow 2NaOH + H_2$

Consider the following reaction to form ammonia: any ammonia molecule is always made up of three hydrogen (H) atoms and one nitrogen (N) atom in a fixed ratio according to the formula $NH_3$.




| | Reactants before | | Products after |
|---|---|---|---|
| **Word equation** | Hydrogen + nitrogen | React to form | ammonia |
| **Chemical equation** | 3 $H_2$ + $N_2$ | → | 2 $NH_3$ |
| **Atoms** | 6 H<br>2 N | → | 6 H<br>2 N |
| **Total mass of all atoms** | 3 x ( 1+1) + 1 x (14+14)= 34 | → | 2 x (14 + 1+1+1) = 34 |
| **Energy** | Energy used to break:<br>3 x H-H bonds<br>And 1 N-N bond | → | Energy released when forming 6 x N-H bonds |

**Law of conservation of matter**

In a chemical reaction, the sum of the mass of the reactants equal the sum of the mass of the products.
Total mass of reactants = total mass of products.

Worked Example: Verify the law of conservation of mass in a reaction between lead nitrate and sodium iodide solutions.

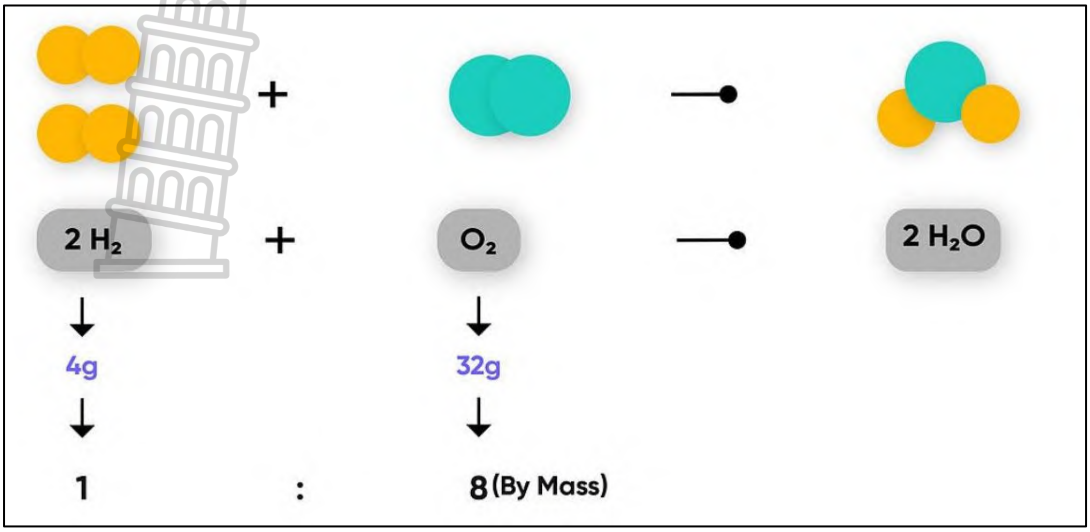
*Answer:*
*The reaction must be balanced.*
*Total relative mass before and after the reaction:*

$Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$
*331,2 + (2 x 149,9) → 461,0 + (2 x 85)*
*631,0 → 631,0*

*The mass of the reactants is equal to the mass of the products.*
*Matter (in this case atoms) are neither created nor destroyed but they are simply combined or arranged differently.*
Mass of reactants = mass of products.

***The law of Constant Composition***

No matter how a chemical compound is prepared, it always contains the same elements in the same ratio.



**QUESTION 1: MULTIPLE-CHOICE QUESTIONS**

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer.

1.1 In a physical change, which one of the following statements is true?

A Mass is conserved and the energy of the products is different from that of the reactants.

B Mass is not conserved and the energy of the products is the same as that of the reactants.

C Mass is not conserved and the energy of the products is different from that of the reactants.

D Mass is conserved and the energy of the products is the same as that of the reactants. (2)

1.2 Which of the following represents a physical change?

A $HCl + Zn \rightarrow ZnCl_2 + H_2$

B $H_2O_{(g)} \rightarrow H_2O_{(l)}$

C $H_2SO_4 + NaOH \rightarrow Na_2SO_4 + H_2O$

D $A + B \rightarrow AB$

(2)

1.3 Which ONE of the following is true for a physical change?

A It is reversible and the number of atoms in a molecule changes

B It is irreversible and the number of atoms remain the same

C It is reversible and the number of atoms remain the same

D It is irreversible and the number of atoms in a molecule changes. (2)

1.4 Which of the following represent a balanced chemical equation?

A $2Hg + O_2 \rightarrow HgO$

B $2Hg + 2O_2 \rightarrow 4HgO$

C $Hg + O_2 \rightarrow HgO$

D $2Hg + O_2 \rightarrow 2HgO$ (2)

1.5 Carbon dioxide can change directly from solid to gas. What is this process known as?

A Decomposition

B Evaporation

C Sublimation

D Melting (2)

1.6 What are the missing coefficients for the following equation?

$Al_2(SO_4)_3(aq) + KOH(aq) \qquad Al(OH)_3(aq) + K_2SO_4(aq)$

A 1, 3, 2, 3

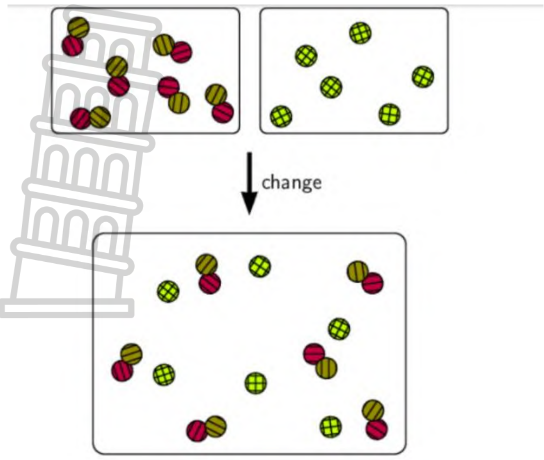
B 2, 12, 4, 6

C 4, 6, 2, 3

D 1, 6, 2, 3 (2)

**QUESTION 2**

Examine the diagram below and answer the questions that follow

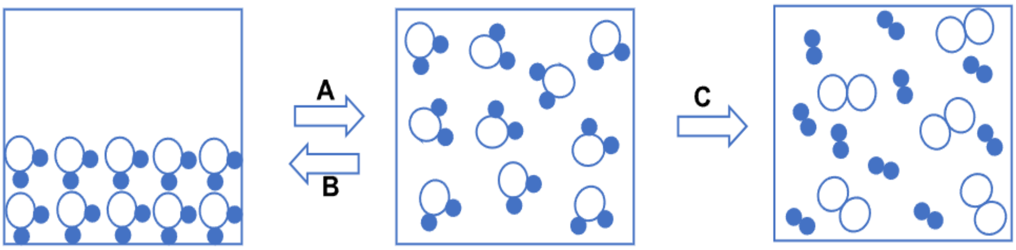



2.1 What type of change does the figure show? (1)

2.2 Give a reason for the answer. (2)

**QUESTION 3**

3.1 Study the illustration below and answer the questions that follow.




3.1.1 Is process A showing a physical or chemical change? (1)

3.1.2 Give 2 reasons for the answer to Question 3.1.1. (2)

3.1.3 Is process B showing a physical or chemical change? (1)

3.1.4 Is process C showing a physical or chemical change? (1)

3.1.5 Give a reason for the answer to question 3.1.4 (1)

3.2 Complete the following table by indicating whether each of the descriptions is an example of a physical or chemical change.

**Physical & Chemical changes/example**

| | **Description** | **Physical or Chemical** |
|---|---|---|
| 3.2.1 | Hot and cold water mixed | |
| 3.2.2 | Milk turns sour | |
| 3.2.3 | A car starts to rust | |
| 3.2.4 | Carbon dioxide gas is bubbled through lime water | |
| 3.2.5 | Water from a dam is purified with chlorine | |
| 3.2.6 | Nitrogen is separated from air using fractional distillation. | |

(6)

**QUESTION 4**

The unbalanced chemical equation (i) and the word equation (ii) for two chemical reactions are shown below.

(i) $Cl_2(g) + H_2(g) \rightarrow HCl(g)$

Aluminium carbonate → aluminium oxide + carbon dioxide

4.1 What does the (g) in reaction (i) represent? (1)

4.2 Write down the chemical formulae of the following:

4.2.1 Aluminium carbonate (2)

4.2.2 Aluminium oxide (2)

4.3 Write a balanced equation for equation (i) (3)

4.4 Use the balanced equation in QUESTION 4.3 to show that mass is conserved in a chemical reaction. (3)

**[11]**

**PHYSICAL AND CHEMICAL CHANGE: SOLUTIONS**

**Question 1**

1.1 D
1.2 B
1.3 C
1.4 D
1.5 C
1.6 D

**Question 2**

2.1 Physical change
2.2
- No new substances are formed
- The number of atoms, molecules and mass is conserved

**Question 3**

3.1

3.1.1 Physical Change
3.1.2
- No new substances are formed
- The number of atoms, molecules and mass is conserved

3.1.3 Physical Change

3.1.4 Chemical Change

3.1.5
- New substances are formed
- The number of have molecules changed

3.2 

3.2.1 Physical
3.2.2 Chemical

3.2.3 Chemical

3.2.4 Chemical

3.2.5 Chemical

3.2.6 Physical

**Question 4**

4.1 Gas

4.2

4.2.1 $Al_2(CO_3)_3$

4.2.2 $Al_2O_3$

4.3 $Cl_{2(g)} + H_{2(g)} \rightarrow 2HCl_{(g)}$

4.4 $Cl_{2(g)} + H_{2(g)} \rightarrow 2HCl_{(g)}$

Mass of the reactants = (35.5 x 2) + (1 x 2)=73 g

Mass of the products = 2(36.5)= 73g

Mass of reactants = mass of products

Therefore, Mass is conserved.

**(REPRESENTING CHEMICAL CHANGE, CONSERVATION OF MASS)**
**QUESTION 5**
Balance the following chemical equations:

5.1 $Fe + Cl_2 \rightarrow FeCl_3$

5.2 $Fe + O_2 \rightarrow Fe_2O_3$

5.3 $FeBr_3 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + HBr$

5.4 $(NH_4)_3PO_4 + Pb(NO_3)_4 \rightarrow Pb_3(PO_4)_4 + NH_4NO_3$

**SOLUTIONS**

5.1 $2Fe + 3Cl_2 = 2FeCl_3$

5.2 $4Fe + 3O_2 = 2Fe_2O_3$

5.3 $2FeBr_3 + 3H_2SO_4 = Fe_2(SO_4)_3 + 6HBr$

5.4 $4(NH_4)_3PO_4 + 3Pb(NO_3)_4 = Pb_3(PO_4)_4 + 12\ NH_4NO_3$

**QUANTITATIVE ASPECTS OF CHEMICAL CHANGE**

Prior knowledge to revise:

- Writing chemical formula
- Calculation of Relative Formula Mass
- Balancing chemical equations

**The Concept of the Mole**

The mole is described as the SI (standard international) unit for amount of substance.

One mole of any substance is defined as the amount of substance having the same number of particles as there are atoms in 12 g carbon-12.
There are 6,02 x $10^{23}$ atoms in 12g carbon-12. Therefore, one mole of a substance will have 6,02 x $10^{23}$ particles.

**Avogadro's number ($N_A$)**

This is the number of particles (atoms, molecules, formula units) present in one mole of a substance.
($N_A$ = 6,02 x $10^{23}$ $mol^{-1}$)

Converting a given number of particles of a substance to moles: $n = \frac{N}{N_A}$

n: number of moles
N: number of particles (atoms, molecules, formula-units)
$N_A$: Avogadro's Number

Worked Example

1. Determine the number of moles of $H_2O$ in 1,806 x $10^{24}$ molecules of water.

*Solution*: $n = \frac{N}{N_A}$

$$n = \frac{1{,}806 \times 10^{24}}{6{,}02 \times 10^{23}} = 3 \text{ moles}$$

2. Calculate the total number of atoms in 0,5 moles of $CO_2$.

*Solution*:

Number of $CO_2$ molecules: = n x $N_A$ = 0,5 x 6,02x$10^{23}$ = 3,01 x $10^{23}$.

BUT each $CO_2$ has 1 Carbon atom and 2 Oxygen atoms
Number of C atoms = 1 x 3,01x$10^{23}$ = 3,01x$10^{23}$ atoms
Number of O atoms = 2 x 3,01x$10^{23}$ = 6,02x$10^{23}$ atoms

Total number of atoms = 3,01x$10^{23}$ + 6,02x$10^{23}$ = 9,03x$10^{23}$ atoms
OR
Total number of atoms = 3 x 3,01x$10^{23}$ = 9,03x$10^{23}$ atoms
↓
1C atom + 2O atoms

**Multiple Choice Questions**

1 Which of the following numbers is equal to Avogadro's number?

A number of atoms in 1 mole of $H_2O$

B number of atoms in 1 mole $Cl_2$

C number of atoms in 2 moles of $Cl_2$

D number of atoms in 0.5 moles of $N_2$ (2)

2 The total number of atoms in 1 molecule of $(COOH)_2.2H_2O$

A $6.02 \times 10^{23}$

B 11

C 12

D 14 (2)

3 If each of the sample of gases below has a mass of 20 g, which sample has the greatest number of moles?

A $NH_3$

B $N_2$

C $H_2$

D $CO_2$ (2)

4 How many moles of $H_2O(l)$ will form if 126g of ice [$H_2O(s)$] is completely melted into a liquid?

A 1

B 7

C $7 \times 6{,}02 \times 10^{23}$

D $6{,}02 \times 10^{23}$ (2)

**Relationship between number of moles (n), mass (m) and molar mass(M)**

Molar mass: The mass of one mole of a substance measured in $g \cdot mol^{-1}$.

Formula: $n = \frac{m}{M}$
n: number of moles
m: mass in g
M: molar mass in $g.mol^{-1}$ (obtained by adding the atomic masses (A) from periodic table)

Worked Example

1. Find the molar mass of:

1.1 $H_2SO_4$

*Solution*: From the periodic table: Atomic Mass (H) =1 $g.mol^{-1}$;
Atomic Mass (S) = 32 $g.mol^{-1}$; Atomic Mass (O) = 16 $g.mol^{-1}$
The molecule has 2 H atoms, 1 S atom and 4 O atoms (obtained from the formula $H_2SO_4$)
$M(H_2SO_4) = 2(1) + 1(32) + 4(16) = 98\ g.mol^{-1}$

1.2 $Ca(NO_3)_2$

*Solution*:
Note: The “2” outside the bracket is ONLY used to find the number of each atom within the bracket.
This molecule has 1 Ca atom, 2x1 N atoms, 2x3 O atoms
$M(Ca(NO_3)_2) = 1(40) + 2(14) + 6(16) = 164\ g.mol^{-1}$

2. Determine the number of moles in 120 g $NH_3$.
Solution:
$M(NH_3) = 1(14) + 3(1) = 17\ g.mol^{-1}$
$n(NH_3) = \frac{m}{M} = \frac{120}{17} = 7{,}06$ moles

**QUESTION 1**
(*Concepts covered: Calculation of number of moles, mass, molar mass and number of molecules, writing chemical formula*)

1.1 Calculate the molar mass of:

1.1.1 $K_2SO_4$ (2)

1.1.2 $Mg_3(PO_4)_2$ (2)

1.1.3 Magnesium Nitrate (3)

1.2 Determine the mass of 2,5 moles $H_2SO_4$. (3)

1.3 Calculate the number of moles in 50 g Magnesium Chloride. (4)

1.4 3 moles of a diatomic element has a mass of 84 g.
Identify the diatomic element using suitable calculations. (4)

1.5 Determine the number of $H_3PO_4$ molecules in 85g of $H_3PO_4$. (4)

**Percentage Composition**

This is the mass of each atom present in a compound expressed as a percentage of the total mass of the compound. (Note: Remember to take into account the number of times the atom appears in the compound).

$$Percentage\ Composition\ of\ Atom = \frac{Atomic\ Mass\ of\ Atoms}{Molar\ Mass\ of\ Compound} \times 100$$

<u>Worked Example</u>

Find the percentage composition of each atom in $Na_2SO_4$.

Solution:
$M(Na_2SO_4) = 2(23) + 1(32) + 4(16) = 142\ g.mol^{-1}$

$$\%Na = \frac{23 \times 2}{142} \times 100 = 32.39\%$$

$$\%S = \frac{32}{142} \times 100 = 22.54\%$$

$$\%O = \frac{16 \times 4}{142} \times 100 = 45.07\%$$

(Note: The sum of the percentage of all atoms in the compound is 100)

**Empirical Formula**
Empirical formula is the simplest whole-number ratio of atoms in a compound.

<u>Steps to determine the Empirical formula from percentage composition</u>
Step 1: Take 100 g of the substance, so that the mass of each element is the given percentage.
Step 2: Calculate the number of moles using the formula $n = m/M$
Step 3: Determine the simplest ratio by dividing the number of moles of each element by the smallest number from step 2. If all values are not whole numbers, multiply throughout by a suitable constant to obtain whole numbers.
Step 4: Write the empirical formula.

<u>Worked Example</u>

Determine the empirical formula of a compound containing 49,31% Carbon, 9,59% Hydrogen, 19,18% Nitrogen and 21,92% Oxygen.

Solution:

Since percentages are given instead of mass of each element, we can use the percentages as masses by taking 100g of the compound.

| Element | mass in 100(g) | $n = \frac{m}{M}$ | Simplest Ratio |
|---|---|---|---|
| C | 49,31 | $\frac{49,31}{12} = 4,11$ | $\frac{4,11}{1,37} = 3$ |
| H | 9,59 | $\frac{9,59}{1} = 9,59$ | $\frac{9,59}{1,37} = 7$ |
| N | 19,18 | $\frac{19,18}{14} = 1,37$ | $\frac{1,37}{1,37} = 1$ |
| O | 21,92 | $\frac{21,92}{16} = 1,37$ | $\frac{1,37}{1,37} = 1$ |
| **Empirical Formula: $C_3H_7NO$** | | | |

Calculating Molecular Formula (True Formula)

If the above compound has a molar mass of 146 g.mol$^{-1}$
Determine the Molecular Formula

$$n = \frac{MolarMass}{EmpiricalFormularMass}$$

$$= \frac{146}{73}$$

$$= 2$$

n: is the value with which you multiply the simplest ratio to get the molecular formula.
Therefore, the molecular formula of the compound will be:
**$2(C_3H_7NO) = C_6H_{14}N_2O_2$**

(2)

**QUESTION 2**
*(Concepts covered: Percentage Composition, Empirical Formula)*

2.1 Determine the percentage of:

2.1.1 Chromium in $K_2Cr_2O_7$ (2)

2.1.2 Oxygen in Calcium Phosphate (2)

2.2 Calculate the mass of oxygen in 24 grams of $H_2O$ (3)

2.3 A laboratory analysis of an organic compound, that contains Carbon, Hydrogen and Oxygen only provided the following percentage composition by mass.

Carbon: 60%
Hydrogen: 4.44%
Oxygen: X %

2.3.1 Calculate X the percentage of Oxygen in the molecule. (2)

2.3.2 Determine the empirical formula of this compound (5)

**Hydrated Salts**

Some ionic crystals trap a certain number of water molecules between the ions as they are forming. These water molecules are known as “Water of crystallization”.

Water of crystallisation is defined as water that is stoichiometrically bound into a crystal.

A hydrated salt is a crystalline salt molecule that is loosely attached to a certain number of water molecules, e.g. $MgSO_4{\cdot}7H_2O$

$MgSO_4{\cdot}7H_2O$ has 7 $H_2O$ molecules loosely attached to each $MgSO_4$ formula unit. When the hydrated salt crystals are heated, the water molecules evaporate, leaving the anhydrous salt (salt without the $H_20$ molecules behind).
An anhydrous salt is where the crystal has had the water driven out. This is represented in the chemical equation below:

$$MgSO_4{\cdot}7H_2O \rightarrow MgSO_4 + 7H_2O$$

(NOTE: When finding the molar mass of a hydrated salt the dot (·) in the formula between the salt and water is used as an addition of the mass of the water of crystallisation molecules, and NOT as a multiplication).

<u>Worked Example</u>

1. Calculate the molar mass of $H_2C_2O_4{\cdot}2H_2O$

Solution:

$M(H_2C_2O_4{\cdot}2H_2O)$ $= M(H_2C_2O_4) + M(2H_2O)$

$= \underbrace{2x1 + 2x12 + 4x16}_{M(H_2C_2O_4)} + \underbrace{2(2x1 + 16)}_{M(2H_2O)} = 126\ g.mol^{-1}$

2. Calculate n, the number of moles of water of crystallisation in $CoCl_2{\cdot}nH_2O$ if the molar mass is 238 $g{\cdot}mol^{-1}$.

Solution:

$M(CoCl_2{\cdot}nH_2O)$ $= M(CoCl_2) + n\ M(H_2O)$

238 $= 59 + 2x35,5 + n\ (2x1 + 16)$

$n = 6$

**Concentration**

Concentration is defined as the number of moles of solute per cubic decimetre of solution.

Concentration is calculated using one of the following formulae:

$c = \frac{n}{V}$ ……1

$c = \frac{m}{MV}$ ……2

c: concentration in $mol.dm^{-3}$
n: number of moles of solute.
m: mass of solute in g
M: molar mass of solute in $g.mol^{-1}$
V: final volume of solution in $dm^3$

Formula 1 above is useful when working with concentration and number of moles.
Formula 2 above is useful when working with mass and concentration.

Common volume conversions:

$1m^3 = 1000dm^3$
$1dm^3 = 1000cm^3$
$1litre = 1dm^3$
$1000ml = 1000cm^3 = 1dm^3$ (convert ml or $cm^3$ to $dm^3$ by dividing by 1000)

Worked Example

1. Calculate the concentration of 2 moles of HCl dissolved in a volume of 5 $dm^3$ of water.

Solution:

$c = \frac{n}{V}$

$c = \frac{2}{5} = 0.4\ mol \cdot dm^{-3}$

2. 32g of ammonium nitrate ($NH_4NO_3$) is added to sufficient water to obtain a 250 $cm^3$ solution. Calculate the concentration of the solution.

*Solution:*

$M(NH_4NO_3) = 14 + 4x1 + 14 + 3x16 = 80\ g.mol^{-1}$

$c = \frac{m}{MV}$

$c = \frac{32}{80 \times 0.25} = 1.6\ mol.dm^{-3}$

**Molar volume of gases**

Avogadros Law: one mole of any gas occupies the same volume at the same temperature and pressure.
(The volume of 1 mole of a gas depends on the Temperature and Pressure)

We refer to the volume of 1 mole of a gas as the Molar Volume ($V_m$).
Therefore, the Molar Volume of a gas depends on the Temperature and Pressure.

Standard Temperature and Pressure (STP)
Standard Temperature: 273 K or 0ºC
Standard Pressure: 1atm or 101,3 kPa
The Molar Volume ($V_m$) of any gas at STP is 22,4 $dm^3$.

Note: If the temperature is not 273 K or pressure is not 101,3 kPa, the $V_m$ cannot be taken as 22,4 $dm^3$.

The volume of a gas at STP can be obtained from the Molar Volume using the formula below:

$V = n \times V_m$ = n x 22,4 (Gases at STP ONLY)

V: volume of the gas in $dm^3$
n: number of moles of the gas.
$V_m$: Molar Volume of the gas in $dm^3$

Worked Example
Determine the volume of 2 moles of Oxygen gas at STP

Solution:
$V = n \times V_m = 2 \times 22.4 = 44.8\ dm^3$

**QUESTION 3**
*(Concepts covered: Hydrated Salts, Concentration, Molar Volume of Gases)*

3.1 Which one of the following masses of oxygen gas will occupy a volume of 22,4$dm^3$ at STP?

A 8g

B 16g

C 32g

D 64g (2)

3.2 Consider the balanced chemical equation below:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

Which of the volumes would indicate the volume of $SO_3$ formed when 64 g oxygen, $O_2(g)$, completely reacts with $SO_2$ at STP?

A 44,8 $dm^3$

B 11,2 $dm^3$

C 22,4 $dm^3$

D 89,6 $dm^3$ (2)

3.3 14.3 g of a sample of hydrated sodium carbonate, $Na_2CO_3 \cdot xH_2O$, was strongly heated until no further change in mass was recorded. On heating, all the water of crystallisation evaporated as follows:

$$Na_2CO_3 \cdot xH_2O \rightarrow Na_2CO_3 + xH_2O$$

Calculate the number of moles of water of crystallisation, x, in the sodium carbonate sample, if 5.3g of solid remained after strong heating. (5)

3.4 Calculate the mass of NaCl(s) required to create a 250 $cm^3$ solution of concentration 0,5 $mol.dm^{-3}$ (3)

3.5 Determine the number of moles of 25 $cm^3$ Sulphuric Acid with a concentration of 1,75 $mol \cdot dm^{-3}$ (3)

3.6 Determine the volume of 50 g of $SO_2$ gas at STP (4)

3.7 Determine the number of moles of 250 $cm^3$ of $NH_3$ gas at STP (3)

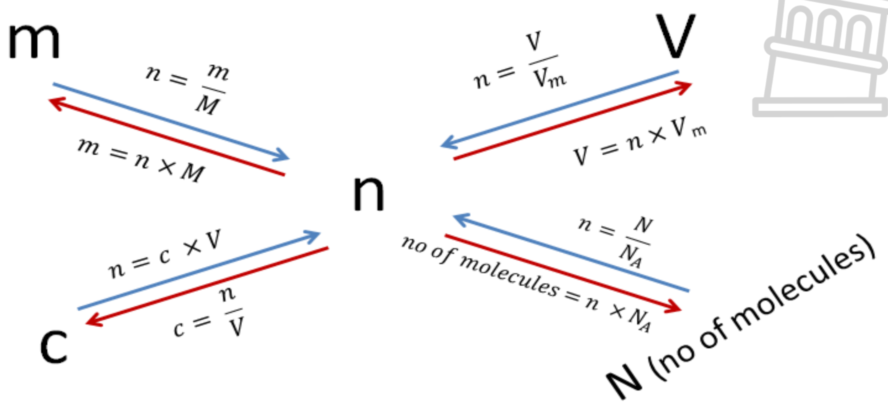
**STOICHIOMETRIC CALCULATIONS**

1. Ensure that the chemical equation is balanced.

2. Identify the substances for which information is given. Use the given information to calculate the number of moles of this component.

3. Use the ratio from the balanced equation to calculate the number of moles of the substance that you are required to calculate.
   - 3.1 Apply the ratio to the number of moles regardless of the phases.
   - 3.2 ONLY when comparing 2 gases, can we take the ratio of the moles to be the ratio of the volume.
   - 3.3 DO NOT apply the stoichiometric coefficients (balancing numbers) as a ratio of masses. This ratio is strictly for the ratio of the moles.
   - 3.4 DO NOT multiply by the coefficient when calculating the molar mass of a substance (The molar mass is the mass of one mole of a substance).

4. Use that number of moles calculated from the ratio to calculate the required quantity.



Worked Example

50 g Nitrogen ($N_2$) is added to Hydrogen ($H_2$) to form Ammonia ($NH_3$).

The balanced chemical equation for the reaction is:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Determine:

1. The mass of $NH_3$ formed.
2. The number of $NH_3$ molecules formed.
3. The volume of $H_2$ required at STP.

Solution:

1. Since the mass of $N_2$ is given, first calculate the n($N_2$).

$n(N_2) = \frac{m}{M}$

$= \frac{50}{2\times14}$ = 1,79 moles

Apply the mole ratio from the balanced reaction to the given information and the required information.

Given Info ⟶ $N_2$ : $NH_3$ ⟵ Required Info

1 : 2 ⟵ Stoichiometric coefficients (ratio)

1,79 : $x$

$x$ = 2x1,79 = 3,58 moles of $NH_3$

Use the number of moles of $NH_3$ to calculate the mass.

m ($NH_3$) = n x M = 3,58 x (14+3) = 60,86 g

2. number of $NH_3$ molecules = n x $N_A$

= 3,58 x 6,02x$10^{23}$ = 2,16 x $10^{24}$ molecules

3. Given Information: $N_2$ : $H_2$ ⟵ Required Info

1 : 3 ⟵ Stoichiometric coefficients (ratio)

1,79 : $x$

$x$ = 3x1,79 = 5,37 moles of $H_2$

Since we are working at STP: $V_m$ = 22,4 $dm^3$

V ($H_2$) = n x $V_m$ = 5,37 x 22,4 = 120,29 $dm^3$

**QUESTION 4**

*(Concepts Covered: Calculation of no of moles, Molar Volume, Stoichiometric ratios, Balancing chemical equations)*

The first step in the extraction of zinc from zinc sulphide (ZnS) is the reaction of ZnS with oxygen (combustion of ZnS). The UNBALANCED equation for the reaction is:

$$ZnS(s) + O_2(g) \rightarrow ZnO(s) + SO_2(g)$$

During this reaction, 7g of ZnS reacts completely with oxygen gas [$O_2$ (g)]

4.1 Rewrite and balance the chemical equation for the reaction (2)

4.2 Calculate the:

4.2.1 Number of moles of ZnS that reacted (3)

4.2.2 Mass of $O_2$ that reacted (4)

4.2.3 Volume of $SO_2$ (g) formed at STP (4)

**Percentage Yield**

- Using stoichiometric calculations, we can predict the amount of product we expect to obtain. This amount is known as the *theoretical yield*.
- The actual amount obtained may not be the same as the theoretical yield. This amount is known as the actual yield.
- The actual yield may be calculated as a percentage of the theoretical yield. This is known as the percentage yield.

$$\% \, \boldsymbol{Yield} = \frac{\boldsymbol{Actual\ Yield}}{\boldsymbol{Theoretical\ Yield}} \times \mathbf{100}$$

**QUESTION 5**

*(Concepts covered: Determining number of moles from concentration, stoichiometric calculations, calculation of number of molecules, percentage yield)*

5.1 The reaction between magnesium and dilute hydrochloric acid is represented by the balanced equation below:

$$Mg(s) + 2HC\ell(aq) \rightarrow MgC\ell_2(aq) + H_2(g)$$

During an experiment, 1250 $cm^3$ hydrochloric acid of concentration 0,1 $mol.dm^{-3}$ reacts with excess magnesium to produce hydrogen gas at STP.

Calculate the:

5.1.1 mass (in grams) of hydrogen gas that is expected. (4)

5.1.2 number of hydrogen atoms formed. (4)

5.2 Excess steam, $H_2O(g)$, reacts with methane, $CH_4(g)$, industrially according to the reaction:

$$H_2O(g) + CH_4(g) \rightarrow 3H_2(g) + CO(g)$$

In a reaction, 41,4 $dm^3$ of methane was reacted with steam, producing 55,89 $dm^3$ of hydrogen gas, $H_2(g)$.
Calculate the percentage yield of hydrogen gas. (5)

5.3 Nitrogen gas reacts with excess Hydrogen gas according to the following balanced reaction:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

In the reaction, ***x*** grams of $N_2$ was reacted with excess $H_2$ and produced 12.5 grams of ammonia gas. If the percentage yield for the reaction is 75%, calculate the mass of $N_2$ gas required for the reaction.
(6)

**<u>QUANTITATIVE ASPECTS OF CHEMICAL CHANGE: SOLUTIONS</u>**

**Multiple choice questions**

1. D
2. D
3. C
4. B

**QUESTION 1**

1.1.1 M = (39X2)+32+(16X4) = 174 g.mol$^{-1}$

1.1.2 M = (24X3)+(95X2) = 262 g.mol$^{-1}$

1.1.3 M = (24+14X2)+(16X6) = 148 g.mol$^{-1}$

1.2 m = n x M

m = 2.5 X 98

m = 245 g

1.3 $n = \frac{m}{M}$

$= \frac{50}{95}$

=0.526 mols

1.4 $n = \frac{m}{M}$

$= \frac{84}{3}$

= 28 g.mol$^{-1}$ Therefore, the molecule will be $N_2$

1.5 $n = \frac{m}{M}$

$= \frac{85}{95}$

= 0.867 mols

N = n x $N_A$

= (0.867) (6.02 x $10^{23}$)

= 5.219 x $10^{23}$ molecules

**Question 2**

2.1

2.1.1 Total molar mass = ( 39x2)+(52x2)+(16x7)=294 g.mol$^{-1}$

%Cr = $\frac{104}{294}$ x 100= 35.37%

2.1.2 Total molar mass = (40x3)+(31x2)+(16x8) = 310 g.mol$^{-1}$

%O = $\frac{128}{310}$ x 100 = 41,29%

2.2 % of oxygen in $H_2O = \frac{16}{18} \times 100 = 88{,}89\%$

Mass of oxygen = $\frac{88.89}{100} \times 24 = 21{,}33$ grams

2.3

2.3.1 x = 100 - (60+4.44) = 35.56%

2.3.2

| Elements | $n = \frac{m}{M}$ | Divide by the smallest value | Ratio | Ratio |
|---|---|---|---|---|
| C | $\frac{60}{12} = 5$ | $\frac{5}{2.22} = 2.25$ | 2.25 x 4 | 9 |
| H | $\frac{4.44}{1} = 4.44$ | $\frac{4.44}{2.22} = 2$ | 2 x 4 | 8 |
| O | $\frac{35.56}{16} = 2.22$ | $\frac{2.22}{2.22} = 1$ | 1 x 4 | 4 |
| Empirical formula: **$C_9H_8O_4$** | | | | |

**Concentration and Molar Volume of Gases: Solutions**

**Question 3**

3.1 C

3.2 D

3.3 Mass of $xH_2O$= 14.3 - 5.3=9 g

Mass of $Na_2CO_3$ =5.3 g

$n(XH_20) = \frac{m}{M}$

$= \frac{9}{18}$

= 0.5 mol

$n(Na_2CO_3) = \frac{m}{M}$

$= \frac{5.3}{106}$

$= 0.05\ mol$ – *smallest ratio*

Divide both number of moles by smallest ratio

0.05 **:** 0.5

1 **:** 10

$Na_2CO_3 . 10H_2O$

3.4

$C = \frac{m}{MV}$

$0.5 = \frac{m}{(58.5)(0.25)}$

M = 7.31 g

3.5

$C = \frac{n}{V}$

$1.75 = \frac{n}{0.025}$

n = 0,044 mols

3.6

$n = \frac{m}{M}$

$= \frac{50}{64}$

= 0.78 mols

$V = n \times V_m$

= 0.78 x 22.4

= 17.5 $dm^3$

3.7

$n = \frac{V}{V_m}$

$= \frac{0.25}{22.4}$

= 0.011 mols

**Question 4**

$2ZnS_{(s)} + 3O_2 \rightarrow 2ZnO_{(s)} + 2SO_{2\,(g)}$

4.2

4.2.1

$n = \frac{m}{M}$

$= \frac{7}{97}$

= 0.07 mols

4.2.2

$ZnS : O_2$

2 : 3

0.07: X

n ($O_2$) = 0.105 mols

m = n x M

= 0.105 x 32

= 3.36 g

4.2.3

$ZnS:SO_2$

1:1

$V = n \times V_m$

$= 0.07 \times 22,4$

$= 1,568\ dm^3$

**Question 5**

**5.1**

5.1.1

$c = \frac{n}{V}$

$0.1 = \frac{n}{1.25}$

n = 0.25 mols

$HCl : H_2$

2 : 1

$n(H_2) = 0.125$ mols

$m = n \times M$

$= 0.125 \times 2$

$= 0.25$ g

5.1.2

$N = n \times N_A$

$= (0.125 \times 2)(6.02 \times 10^{23})$

$= 1.5 \times 10^{23}$ atoms

5.2

$CH_4 : H_2$

1 : 3

41.4 : x

$V(H_2) = 124.2\ dm^3$

$\%Yield = \frac{Actualyield}{Theoteticalyield} \times 100$

$= \frac{55.89}{124.2} \times 100$

= 45%

5.3

$\text{Theoretical Yield} = \frac{actualyield}{\%Yield}$

$= \frac{12.5}{0.75}$

= 16.66 g

$N_2 : NH_3$

1 : 2

$n(N_2) = \frac{0.98}{2}$

n = 0.49 mols

$n(NH_3) = \frac{m}{M}$

$= \frac{16,66}{17}$

= 0.98 mols

$mass(N_2) = n \times M$

$= 0.49 \times 28$

= 13,72 g

**VECTORS AND SCALARS**

**Scalar** quantities have magnitude only.
**examples:** mass, charge, energy, time, distance, speed
**Vector** quantities have both magnitude and direction.
**examples:** force, weight, displacement, velocity, acceleration
Vector quantities are represented by arrows called vectors.
In a drawing to scale:

- magnitude of a vector quantity is represented by length of vector
- Direction is indicated by arrowhead.

Equal vectors have the same length and direction.
Negative vectors act in opposite direction to chosen positive direction.
Vectors can be added and subtracted and their magnitudes can be multiplied.
A resultant vector is the single vector that has the same effect as two or more vectors acting together.
Resultant vectors can be determined: graphically, using the tail-to-head and tail-to-tail methods by calculation.

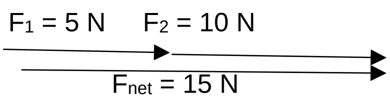
| **Scalar Quantity** | **Vector Quantity** |
|---|---|
| A physical quantity with **magnitude only** | A physical quantity with both **magnitude and direction** |
| examples:<br><br>mass (kg), distance (m), speed ($m.s^{-1}$), time (s),energy (J), temperature (K) | Examples:<br><br>force (N), weight (N), displacement (m), velocity ($m.s^{-1}$), acceleration ($m.s^{-2}$) |

Graphical representation of a vector
+ and – are used to indicate direction of vector
eg. right is +: ——————→ +5 N
left is -: ←———— -3 N

NET OR RESULTANT VECTOR
Single vector that has the same effect as two or more vectors acting together.
Net vector is greatest when vectors are in the same direction.
Net vector is smallest when vectors are in opposite directions.

**Vectors in same direction**

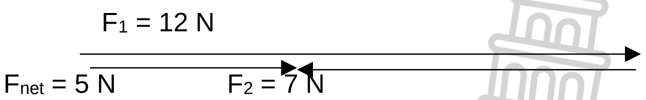
Determine the net force when a 5 N force acts to the right and a 10 N force also acts to the right.




Let to the right be positive
Fnet = $F_1 + F_2$
= 5 + 10
= 15 N right

**Vectors in opposite directions**

Determine the net force when a 12 N force acts to the right and a 7 N force acts to the left.




Let to the right be positive
Fnet = $F_1 + F_2$
= 12 + (-7)
= 5 N right

**WORKED EXAMPLE:**

Consider the physical quantities mass, weight, distance, displacement, speed, velocity, acceleration and energy.

1.1 Give the name and abbreviation of the unit(s) in which each is measured. (8)

1.2 List those that are vector quantities and those that are scalar quantities. (8)

1.3 Using a scale of 10 mm to represent 10 m, draw vectors to represent:

1.3.1 a displacement of 50 m north (2)

1.3.2 a displacement of 80 m east (2)

1.4 Find the resultant of two forces $F_1 = 50$ N and $F_2 = 80$ N graphically:

1.4.1 if they both act to the right (3)

1.4.2 if the 50 N vector acts to the right and the 80 N vector acts to the left (3)

1.4.3 if the 50 N vector acts to the left and the 80 N vector acts to the right (3)

**[29]**

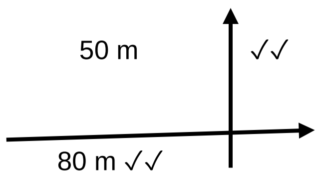
**SOLUTIONS**

1.1 mass (kg), weight (N), distance (m),displacement (m), speed (m.s$^{-1}$), velocity (m.s-1), acceleration (m.s$^{-2}$), energy (J)

1.2 Vectors : weight (N),displacement (m) velocity (m.s$^{-1}$),acceleration (m.s$^{-2}$)
Scalars: mass (kg), distance (m), speed (m.s-1), energy (J)

1.3

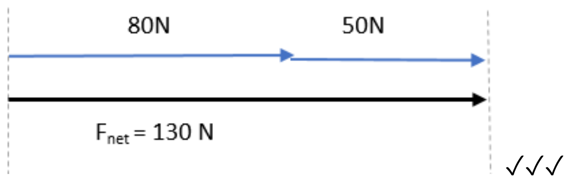
1.3.1 (2)



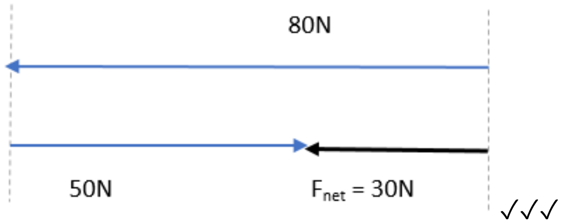

1.3.2 (2)

1.4

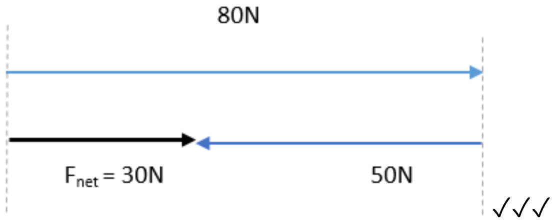
1.4.1 (3)




1.4.2 (3)




1.4.3 (3)




**ACTIVITIES: VECTORS AND SCALARS**

**MULTIPLE CHOICE QUESTION: QUESTION**

1.1 Which ONE of the following physical quantities is a scalar?

A Weight
B Displacement
C Mass
D Velocity

1.2 Which ONE of the following combinations includes TWO vector quantities and ONE scar quantity?

A Displacement, time, speed.
B Velocity, distance, Force.
C Speed, time, acceleration.
D Displacement, acceleration, velocity.

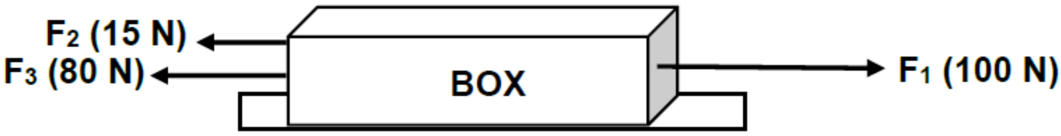
1.3 Two forces Y and Z act on an object which does not move. Which statement below is correct?
The two forces:
A Are equal.
B Act in the same direction.
C Act in opposite directions.
D Are equal and act in opposite directions.

**SOLUTIONS**

1.1 C✓✓
1.2 B✓✓
1.3 D✓✓

**QUESTION 2**

2.1 In the diagram below, a box which is on a smooth surface start moving when three forces $F_1$, $F_2$ and $F_3$ acts on it.

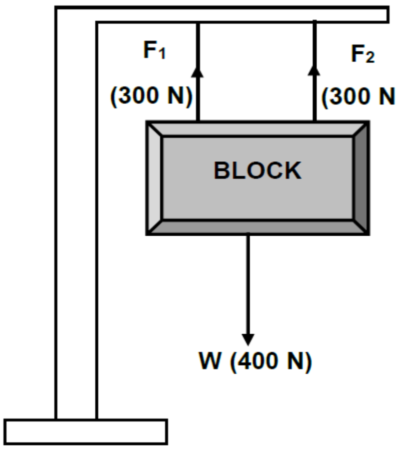



2.1.1 Define the term resultant of a number of forces. (2)

2.1.2 Calculate the magnitude and direction of the resultant force acting on the box. (3)

2.1.3 In which direction will the box move? Write only LEFT or RIGHT. (1)

2.2 A rectangular block is vertically suspended by two forces $F_1$ (300 N) and $F_2$(300 N) in the strings as shown below.




The weight of the block lifted is 400 N.

2.2.1 Give a reason why the forces in the diagram above are referred to as vectors. (2)

2.2.2 Using a scale of 1cm representing 100 N, draw a scale diagram to determine the resultant of forces $F_1$, $F_2$ and W. (3)

Label all for forces clearly including the resultant force.

**[11]**

**SOLUTIONS**

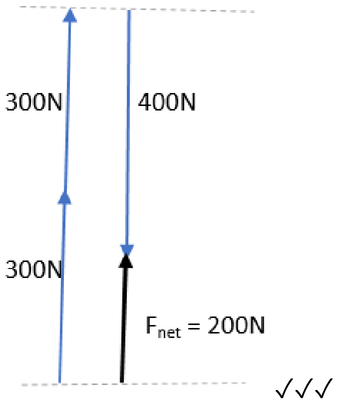
2.1.1 Resultant vector is the single vector that has the same effect as two or more vectors acting together. ✓✓

2.1.2 $F_{net} = F_1 + F_2 + F_3$
$= 100 + (-15) + (-80)$ ✓✓
$= 5N$ to the right✓

2.1.3 RIGHT✓

2.2.1 Vector quantities have both magnitude and direction✓✓

2.2.2



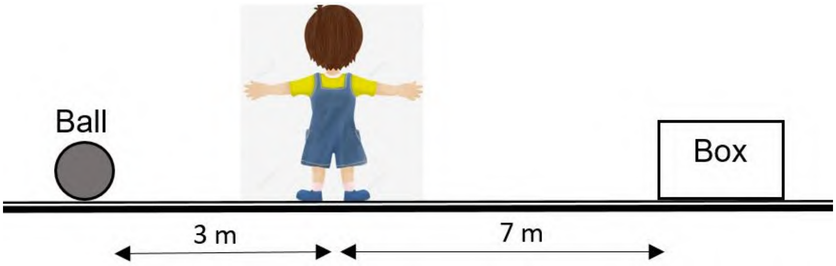

**MOTION IN ONE DIMENSION**

**Frame of reference**

Coordinate system used to represent and measure properties of objects, such as position.
A frame of reference has an origin and a set of directions, such as East and west, up and down …

**Position**

The location of an object relative to a reference point.
Position is a vector. It will be denoted by **x**.
Example: A ball, a boy and a box are stationary on straight horizontal floor.




- Taking the ball as reference point (Zero position):

The boy is 3 m to the right of the ball and the box is 10 m to the right of the box.

- Taking the boy as zero position:

The ball is 3 m to the left of the boy and the box is 7 m to the right of the boy.

**One-dimensional motion**

A motion along a straight line. The object may move forward or backward along this line.

**Distance**

The total path length travelled.
Distance is a **scalar** quantity, expressed in metres (m). It is denoted by D.

**Displacement**

The change in position of an object.
It is the length of a straight line joining the initial to the final position.
Displacement is a **vector** quantity, also expressed in metres. It is denoted by $\Delta x$.
$\Delta x = x_f - x_i$ ($x_f$: final position and $x_i$: initial position).

**Average speed**

The total distance travelled per total time.

$$average\ speed = \frac{Distance}{time}$$

Average speed is a **scalar** quantity, expressed in metres per second ($m.s^{-1}$).

**Average velocity**

The rate of change of position. (vector quantity)

$v = \frac{\Delta x}{\Delta t}$

Average velocity is a **vector** quantity, expressed in metres per second ($m.s^{-1}$).

**Acceleration**

The rate of change of velocity.

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration is a **vector** quantity, expressed in metres per second squared ($m.s^{-2}$).

**Positive acceleration**:

An object moving in the positive direction is experiencing an increase in speed and an object moving in the negative direction is experiencing a decrease in speed.

**Negative acceleration**:

An object moving in the positive direction is experiencing a decrease in speed and an object moving in the negative direction is experiencing an increase in speed.

Deceleration:

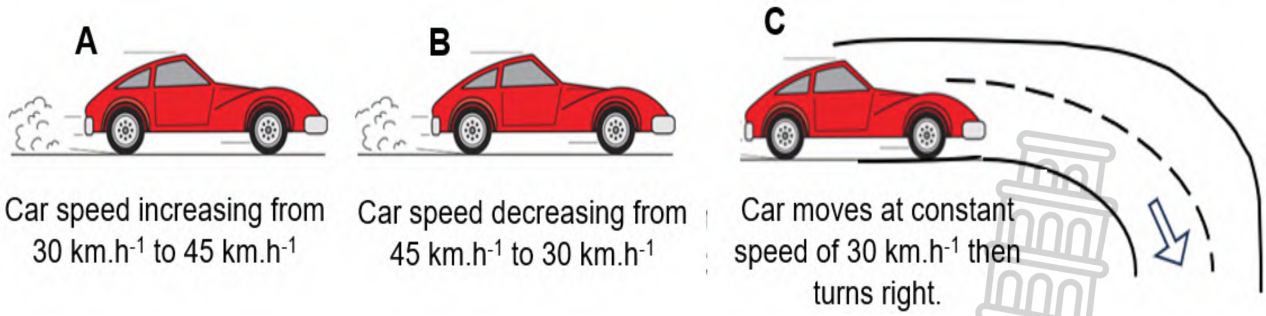
An object is experiencing a decrease in speed.

Example

1. In which case A or B is acceleration involved?


No acceleration in both cases, because velocity remains constant.

2. In which case A, B or C is acceleration involved?




In all the three cases above there is acceleration:

In A, there is a change in magnitude of velocity from 30 $km.h^{-1}$ to 45 $km.h^{-1}$.

In B, there is a change in magnitude of velocity from 45 $km.h^{-1}$ to 30 $km.h^{-1}$.

In C, there is a change in direction, even if the velocity does not change.

Acceleration is a vector quantity, so change in direction result in a change in velocity.

**Conversion of units**

- Converting cm to m, divide by 100.
- Converting mm to m, divide by 1000.
- Converting minutes to seconds, divide by 60.
- Converting hours to seconds, divide by 3600.
- Converting $km.h^{-1}$ to $m.s^{-1}$, Multiply by $\frac{1000}{3600}$

E.g. 25 km.h$^{-1}$ = $25\ x\ \frac{1000}{3600} = 6{,}94\ m \cdot s^{-1}$

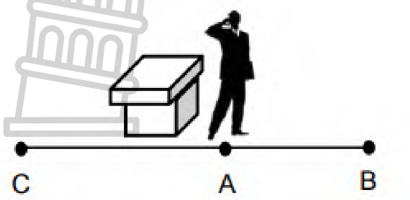
- Converting m.s$^{-1}$ to km.h$^{-1}$, multiply by $\frac{3600}{1000}$

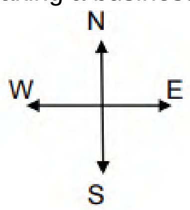
30 m.s$^{-1}$ = $30\ x\ \frac{3600}{1000} = 108\ km \cdot h^{-1}$

**WORKED EXAMPLES**

**EXAMPLE 1**

An impatient businessman paces up and down while making a business call on his Cellphone.




He starts at his desk and walks 5 m east (from A to B) and then walks 7 m west (from B to C). This process takes him 20 s.

| | | |
|---|---|---|
| 1.1 | What is the businessman's change in position at C relative to A? | (2) |
| 1.2 | Calculate the total distance the man covers. | (2) |
| 1.3 | Explain why the value calculated in QUESTION 1.1 differs from the one calculated in QUESTION 1.2 | (2) |
| 1.4 | Define the term velocity. | (2) |
| 1.5 | Calculate the man's average velocity. | (4) |
| | | **[12]** |

**SOLUTIONS**

1.1 2 m ✓ to the left ✓ (2)

1.2 Total distance = 5 + 7 ✓ (2)

= 12 m ✓

1.3 For the total distance, the whole path length travelled is considered.✓ (2)

For change in position, only the original position and final position ✓ of the man are considered.

1.4 Velocity is the rate of change of displacement. ✓✓ (2)

1.5 $v = \frac{\Delta x}{\Delta t}$ ✓ (4)

$= \frac{2}{20}$ ✓

$= 0{,}1\ m \cdot s^{-1}$ ✓ west / to left ✓

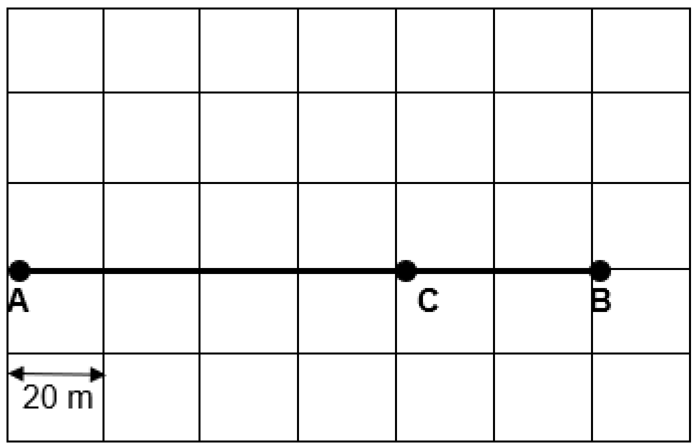
**[12]**

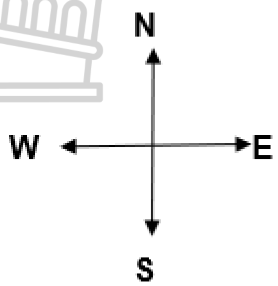
**EXAMPLE 2**

A girl walks from her home at point A to a shop located at point B. On her return she stops at a friend's house at point C.

The girl walks on a flat horizontal surface past houses with yards that are squares of 20 m length each, as shown in the diagram.

She completes the motion from point A to point C in 300 s.



Point B and C are both east of point A.

2.1 Define the term distance (2)

2.2. For the motion of the girl from point A to C, calculate the:

- 2.2.1 Total distance covered (2)
- 2.2.2 Girl's average speed (3)
- 2.2.3 Total displacement (2)

**[9]**

**SOLUTIONS**

2.1 The total path length travelled ✓✓ (2)

2.2.1 Total distance = 160 m ✓✓ (2)

2.2.2 $Average\ speed\ = \frac{distance\ travelled}{time\ taken}$ ✓ (3)

$= \frac{160}{300}$ ✓

$= 0.53\ m \cdot s^{-1}$ ✓

2.2.3 Displacement = 4 x 20 ✓ (2)

= 80 m ✓

**[9]**

**ACTIVITIES**

**QUESTION 1: MULTIPLE CHOICE QUESTIONS**

1.1 A cricket ball is thrown vertically upwards and reaches a height of 18 m above the ground. On the way down it gets stuck in a tree 10 m above the ground. What is the resultant displacement of the ball?

A 10 m downwards

B 10 m upwards

C 8 m downwards

D 8 m upwards (2)

1.2 A car sets out from town X and travels 40 km along a straight road to town Y. The driver turns around and immediately drives back to town X. The whole trip takes 2 hours.
The magnitude of the average velocity for the whole journey, in kilometres per hour, will be …

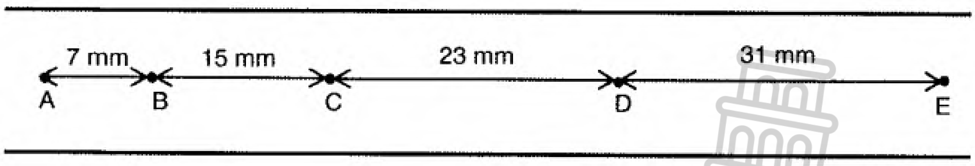
A 0

B 20

C 40

D 80 (2)

1.3 A trolley runs down a slope, pulling a ticker tape behind it through a ticker timer. A portion of the tape is shown below and represents the distances moved during equal time intervals.




The ticker tape represents an acceleration that is …

A Zero

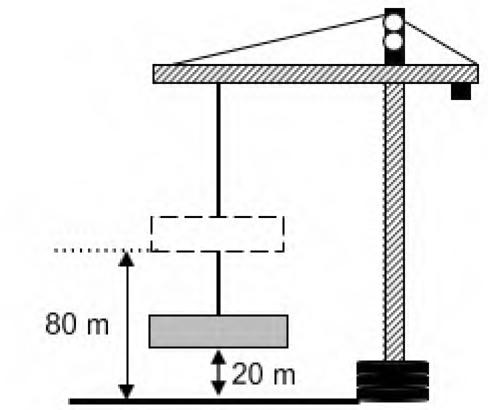
B Uniform

C Increasing

D Decreasing (2)

**Question 2**

The crate is lifted to a vertical height of 80 m above the ground and then lowered to a height of 20 m above the ground as shown in the diagram below.




2.1 Define the term Displacement (2)

2.2 Calculate the :

2.2.1 Total distance travelled by the crate (2)

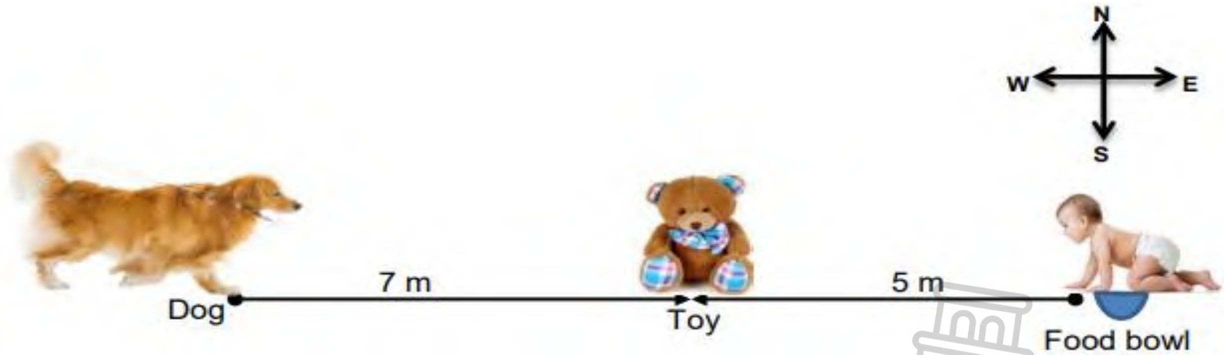
2.2.2 Displacement of the crate (1)

2.3 The cable between the crane and the crate suddenly breaks and the crate falls at 9.8 $m.s^{-2}$. At what velocity will the crate hit the ground if it takes the crate 3 s to reach the ground? (4)

**[9]**

**Question 3**

A baby leaves a bowl of food on the floor and crawls westwards to fetch a toy placed 5 m away. At the same time a dog walks eastwards towards the baby. It takes the baby 30 s to reach the toy. The dog walks past the toy to eat the baby's food in the bowl.




3.1 Define the term displacement in words (2)

3.2 Determine the position of the dog relative to the baby before they both moved. (2)

3.3 Calculate the average velocity of the baby (4)

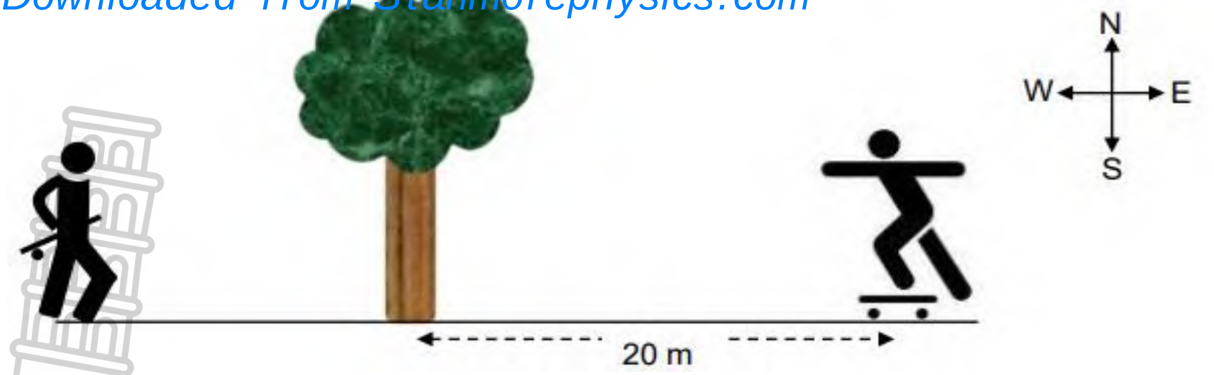
3.4 If the average speed of the dog is TWICE that of the baby, calculate how long it would take the dog to reach the food bowl from the moment the dog started moving. (4)

3.5 Another dog's average velocity changes from 3 $m.s^{-1}$ to 5 $m.s^{-1}$ in 0, 8 seconds. Calculate the dog's acceleration. (4)

**[16]**

**QUESTION 4**

A boy walks in an EASTERLY direction, as shown below. After he passes a tree, he continues in the same direction for another 20 m. He then stops, climbs on his skateboard and rides in a WESTERLY direction for 25 m before he finally stops.




The resultant displacement of the boy when he finally stops is 10 m EAST of his initial position.

4.1 Define the term distance. (2)

4.2 Determine the initial position of the boy relative to the tree. (2)

4.3 Calculate the total distance that the boy moved. (2)

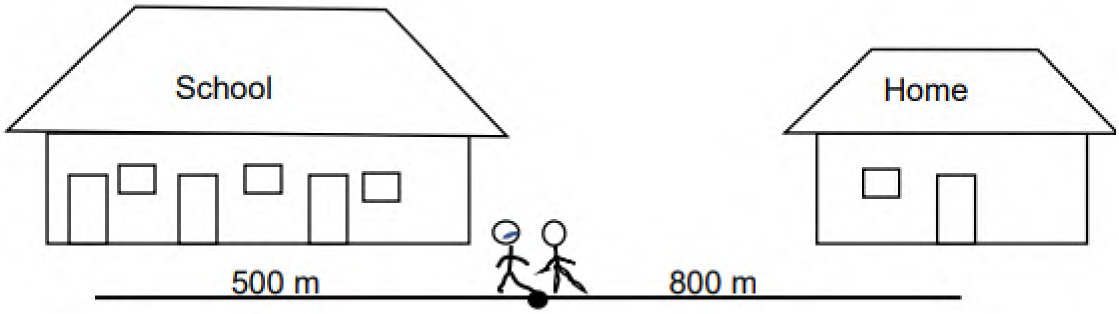
4.4 When the boy is on the skateboard, he skates at an average speed of 5 $m \cdot s^{-1}$.
Calculate how long, in seconds, the boy is on the skateboard during the motion. (3)

4.5 The total time for the motion of the boy from his initial position until he finally stops is 40 s.
Calculate his average velocity. (3)

**[12]**

QUESTION 5

5.1 A brother and sister walk home from school. After walking 500 m eastward, the brother realises that he has left a book at school and he returns to school. His sister continues walking another 800 m to their home. She arrives home 30 minutes after leaving school.

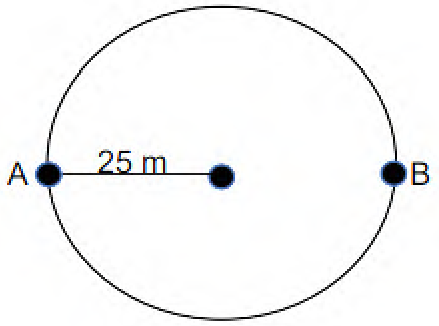



5.1.1 Define the term average speed. (2)

5.1.2 Calculate the average speed of the girl from school to her home. (3)

5.1.3 Calculate how long it would take the boy to reach home, from the time they both left the school together if the average speed of the boy is 0,72 $m.s^{-1}$ (4)

5.2 A girl travels around a circular path from point A to point B. The radius of the circular path is 25 m. Point B is directly east of point A.




Calculate

5.2.1 Distance travelled by the girl (3)

5.2.2 Displacement of the girl (2)

**[14]**

**SOLUTIONS: MOTION IN ONE DIMENSION**

**QUESTION 1**

1.1 B✓✓ (2)

1.2 A✓✓ (2)

1.3 B✓✓ (2)

**[6]**

**QUESTION 2**

2.1 The difference in position in space ✓✓ (2)

2.2.1 Distance = 80 + 60 ✓ (2)
= 140 m ✓

2.2.2 Upward positive: (1)
Displacement = +80 + (-60)
= 20 m ✓ upwards
Upward negative:
Displacement = -80 + 60
= 20 m ✓ upwards

2.3 $a = \frac{\Delta v}{\Delta t}$✓ (4)
$9{,}8$ ✓$= \frac{v_f - 0}{3}$✓
$v_f = 29{,}4\ m.s^{-1}$ ✓

**QUESTION 3**

3.1 The difference in position in space. ✓✓ (2)

3.2 12 m ✓west ✓ or -12 m ✓✓ (2)

3.3 $v = \frac{\Delta x}{\Delta t}$ (4)
$= \frac{5}{30}$✓✓
$= 0{,}17\ m \cdot s^{-1}$✓ west ✓

3.4 $speed = \frac{distance}{time}$ ✓ (4)
$(0{,}17)(2)$ ✓$= \frac{12}{t}$✓
$0{,}34 = \frac{12}{t}$
$t = 35{,}29\ s$ ✓

3.5 $a = \frac{\Delta v}{\Delta t}$✓ (4)
$= \frac{v_f - v_i}{t_f - t_i}$
$= \frac{5-3}{0{,}8-0}$✓
$a = 2{,}5\ ms^{-2}$ ✓ east ✓

**QUESTION 4**

4.1 Total path length travelled. ✓✓ (2)

4.2 Original position = 10 + 5 (2)
= 15 m ✓ west ✓

4.3 Distance = 15 + 20 + 25 ✓ (2)
= 60 m ✓

4.4 $v = \frac{\Delta x}{\Delta t}$ ✓ (3)
$5 = \frac{25}{\Delta t}$ ✓
$\Delta t = 5\ s$ ✓

4.5 $v = \frac{\Delta x}{\Delta t}$ (3)
$= \frac{10}{40}$ ✓
$= 0{,}25\ m \cdot s^{-1}$✓ east ✓

QUESTION 5

5.1.1 The total distance travelled per total time ✓✓ (2)

5.1.2 $v = \frac{\Delta x}{\Delta t}$ ✓ (3)

$= \frac{(500+800)}{1800}$ ✓

$= 0{,}72\ m \cdot s^{-1}$ ✓

5.1.3 $v = \frac{\Delta x}{\Delta t}$ ✓ (4)

$0{,}72$ ✓$= \frac{(500+500+1300)}{\Delta t}$ ✓

$\Delta t = 3194{,}44\ s$ ✓

5.2.1 Distance = ½ x 2πr ✓= ½ 2 x π x 25 = 78,57 m ✓✓ (3)

5.2.2 Displacement = 2 x radius = 50 m ✓ East ✓ (2)